PRODUCTION ENGINEERING MEASURE

FOR MULTILAYER PRINTED WIRING BOARD

Signal Corps Contract Number DA-36-039-SC-86745
Order Number 58502-PP-62-81-81

1st Quarterly Report

1 July 1962

to

30 September 1962

REPORT #1

Photocircuits
CORPORATION
GLEN COVE, NEW YORK

U. S. ARMY SIGNAL SUPPLY AGENCY
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PRODUCTION ENGINEERING MEASURE

FOR MULTILAYER PRINTED WIRING BOARD

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The object of this contract is to establish capability to manufacture Multilayer Printed Wiring per Specification SCS-145 on a pilot run basis in accordance with Step I of SCIPPR No. 15

Signal Corps Contract No.	**DA-36-039-SC-86745**
Order No.	**58502-PP-62-81-81**
Signal Corps Specification	**SCS-145 dated 15 March 1962**

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SECTION I

PURPOSE

1.1 OBJECTIVES

This contract is for Production Engineering Measure in accordance with step I of Signal Corps Industrial Preparedness Procurement Requirement (SCIPPR) No. 15, dated October 1958 for Multilayer Printed Wiring Boards per Specification SCS-145 dated 12 March 1962. The objective is to establish and demonstrate capability to manufacture and test Subminiature Test Pattern Boards per TSS-SCL-7503/1 and Ultraminiature Test Pattern Boards per TSS-SCL-7503/1 at the rate of 60.0 units per eight hour shift.

1.2 PHASES OF WORK

The work on this contract is subdivided into the following phases:

1.2.1 Phase I - Process Engineering

This phase will establish and evaluate the processes needed for production of Multilayer Printed Wiring per Specification SCS-145. The specific tasks of this phase are:

A. Process evaluation
B. Establishment of process sequences
C. Preparation of artwork per SCL 7503B/1 and /2
D. Design and fabrication of prototype tooling
E. Production and evaluation of Engineering Samples.

1.2.2 Phase II - Production Engineering

In this phase the preliminary work for the manufacture of the pre-production run of tests boards will be accomplished such as:

A. Process standards will be prepared and reviewed
B. Process rates will be established
C. Schedules and lead times will be set
D. Incoming material will be investigated and supply sources established
E. Preproduction samples will be manufactured

1.2.3 Phase III - Manufacturing Engineering

During this phase all manufacturing steps and tooling for the pilot run will be formalized and designed. During this phase the following work will be performed:

A. Production equipment analyzed and prepared for the required production rate

B. Manpower requirements established and manpower allocated to sustain the production rate

C. Procurement plan prepared and material flow charts made

D. Production tooling designed and manufactured

E. Pilot runs of test samples at the required production rate made.

1.2.4 Phase IV - Quality Assurance

Work on this phase will be accomplished concurrently with the above described phases and will be concerned with all aspects of quality assurance and testing of samples. The work on this phase will be in the following areas:

A. Establishment of specifications for incoming materials and the testing of such material.

B. Establishment of detailed test procedures for sample testing according to SCL-7503 specifications.

C. Preparation of all equipment and tooling needed for performance of tests according to SCL-7503 specification

D. Establishment of specifications for in-process quality control and for final acceptance checking

E. Preparation of Inspection and Quality Control plan

F. Performance of tests on Engineering and Preproduction samples.

1.2.5 Phase V - Work on High Volume Study

In this phase work on the preparation of the General Report on Step II in accordance with paragraphs 3.2 and 3.8 of SCIPPR No. 15, dated October 1958, covering a minimum rate of 240 units per 8 hour shift will be performed.

It should be noted that work on different phases will be overlapping and therefore no explicit time limitation for each phase is given. Figure 1-1 lists all phases of the work on this contract and gives time references for the various tasks described above.

1.3 RELATED PROJECTS

Photocircuits Corporation is under contract to the U. S. Army Signal Corps for research work directed toward development of Microminiature Layered Printed Wiring. Information or data obtained during the work on this contract which is pertinent to the outlined tasks of the subject contract will be included in the interest of completeness.

SECTION 2

ABSTRACT

In the first quarter of work on the subject contract, the processes required for manufacture of Miniaturized Layered Printed Wiring according to SCL-7503B Specification have been evaluated and a tentative process sequence selected on the basis of production efficiency or contribution to the reliability of the manufactured part. The selected steps have also been tried to insure their adaptability for a high production rate.

Artwork and Tooling needed for the production of preliminary Engineering samples has been completed.

Tentative specifications for qualification testing of the incoming thin copperclad epoxy fiberglass base laminates have been prepared and numerous samples of such materials from various vendors have been tested according to the requirements of this specification.

SECTION 3

PUBLICATIONS AND REPORTS

During the period covered by this report, no lectures have been given or reports published which included any material or data from the work performed under this contract.

SECTION 4

NARRATIVE & DATA

4.1 WORK ON PHASE I

4.1.1 General Remarks

The objective of this phase is to establish processes and process sequences for the manufacture of Miniaturized and Subminiaturized Multilayered Printed Wiring per SCL-7503B Specification. Major tasks of this phase have been completed and the subsequent phases concerned with production and manufacturing engineering will be started as scheduled.

In order to arrive at the most reliable and economically sound manufacturing method, further evaluation of some of presently selected methods will be carried out. Also, an investigation of possible other approaches will be made to insure that the most efficient methods are employed in the production of multilayer boards using the "clearance hole" method of construction.

It is estimated that work on Phase I is about 75% finished. Completion of this phase is scheduled for the end of the second quarter of the contract.

4.1.2 Process Evaluation

Various manufacturing steps presently available for the manufacture of multilayer printed wiring using "clearance hole" construction, have been evaluated according to their merits, engineering soundness and economic or production efficiency. Each of the selected steps has been tried out in production to insure that it will be suitable for the large quantity production rate. The only processes included in the sequence were those which have demonstrated that they are definitely contributing to the quality or reliability of the manufactured parts.

A preliminary time and rate study was conducted on the majority of the selected processes. The results of this study will be re-evaluated when each step is completely standardized and then all collected data will be reported together with information about manpower requirements.

A detailed list of selected steps and a brief description of each step are given in Sections 4.1.3 and 4.1.5.

In conjunction with this process evaluation, a reference should be made to the work performed by International Resistance Company under Signal Corps Contract No. DA-36-039-SC-48941 for Design, Fabrication and Evaluation of Layered Printed Wiring. In the Final Report on the subject contract, a detailed description of the process sequences used to manufacture such Engineering Samples has been given.

During the evaluation of the manufacturing processes, an analysis was made of the production steps used for the manufacture of samples under the above contract and the following remarks can be made:

a. The first eight manufacturing steps of the sequence outlined by IRC deal with the manufacture of copperclad base laminate. The inclusion of these steps in the manufacturing of multilayers is deemed unnecessary since there are numerous qualified manufacturers of fiberglass reinforced epoxy base laminates with thicknesses in the range suitable for multilayer circuitry. The production of base laminates in the same plant which is manufacturing multilayer boards is economically disadvantageous since it unnecessarily burdens the laminating equipment required for high rate production of the circuits. Under the present contract, a thorough qualification testing program of commercially available thin G-10 epoxy base laminates is being conducted. Also, a vendor facility investigation will be made to ascertain that there will be an adequate supply of such base laminates to sustain the required production rate of 60 multilayer boards per 8-hour shift.

b. Engineering samples have been produced by IRC using a dry screen process. It is felt that the line width tolerances and registration problems in the production of Miniaturized and Subminiaturized Multilayer Printed Wiring require the utmost accuracy of pattern reproduction of the individual layers. Therefore the use of a method which gives direct reproduction of the pattern on the copper foil, such as photoprinting, was deemed necessary to avoid intermediate reproduction steps. It is felt that the dimensional advantages of direct reproduction will offset the higher production costs of the photoprinting method.

In the screening process the registry of the pattern is made to the prepunched tooling holes. With the photoprinting method, the tooling holes are reproduced together with the pattern from the same glass and are drilled out after etching. This produces a more accurate alignment of the circuit pattern to the tooling holes.

c. In the sequence used by IRC, the copper foil has oxide film on both sides. This oxide film is used on the surface of etched conductors as a dip solder mask and improves, to a certain degree, the bond strength between the copper and the adhesive during the subsequent lamination. Since the majority of producers of base laminates are not using oxide film on the outside copper surfaces of the laminate, a commercially available eopxy type solder mask must be applied over the conductors before the dip soldering of individual layers in order to prevent solder adhesion to the conductors. Both methods of conductor masking have merits and disadvantages; therefore, an investigation is presently being conducted to determine the best and most economical method. In the meantime, the selected sequence reported here uses the solder mask approach as more compatible with commercially available materials.

d. In regular production runs, Photocircuits Corporation has successfully used the dry lay-up system for lamination of Multilayered Printed Wiring Boards. IRC used a combination of wet and dry methods.

Available test results indicate that the dry method produces parts which will withstand all environmental requirements of SCL-7503 Specification. From an economical standpoint, it is much more logical to use a dry system since it significantly decreases laminating costs and time, is much easier to work with and produces parts equal to the other method.

Since the adhesive used for the dry laminating method flows under heat application and will fill in the holes punched in individual layers, the prepunching of clearance holes in the adhesive is omitted.

e. In their final report, IRC describes certain difficulties with the dielectric properties of manufactured engineering samples. To prevent such difficulties IRC introduced a deionizing treatment of individual layers after etching and a protective coating was applied on the circuit layers prior to lamination. Our present experience indicates that with the application of careful process controls, such measures can be eliminated. If, however, tests of the engineering samples prove that there is need for some additional treatment to improve the dielectric properties of the samples, these special steps might be required.

4.1.3 Process sequences

The following process sequences have been selected for manufacturing Multilayered Printed Wiring according to SCL-7503B Specification:

TABLE 4-1

Step Number	Description	Station Numbers as given in Proposal
1	Inspect Incoming Material	- - -
2	Cut Laminate Sheets to Size	1
3	Greaseless Buff and Clean Copper Surface	2
4	Photoprint with Kodak Photo Resist	3
5	Inspect and Touch-Up	- - -
6	Bake	- - -
7	Spray Etch	4
8	Rinse	- - -
9	Remove Kodak Photo Resist	5
10	Inspect	- - -
11	Drill Tool Holes Optically	6
12	Punch Clearance Holes in Indiv. Layers	9
13	Clean	10
14	Inspect	11
15	Apply Solder Mask	12

Step Number	Description	Station Numbers as given in Proposal
16	Inspect and Touch up	- - -
17	Bake	13
18	Apply Flux to Layers	14
19	Air Dry	14
20	Form Solder Fillets on Pads of Each Layer	14
21	Ultrasonic Clean	15
22	Inspect & Touch up	- - -
23	Ligh Vapor Blast	- - -
24	Rinse	- - -
25	Oven Dry	- - -
26	Cut to Size & Drill Mounting Holes in Adhesive & Backing Material	16
27	Lay up and Laminate	17
28	Trim Flash	- - -
29	Postcure	- - -
30	Drill Component Lead Holes	18
31	Deburr	19
32	Spot Face Terminal Areas	20
33	Clean Holes	21
34	Rough Cut	34
35	Rout to Finished Size and Clean Edges	35
36	Final Inspection, Mechanical	36

Step Number	Description	Station Numbers as given in Proposal
37	Final Inspection, Electrical	37
38	Package and Ship	38

4.1.4 Discussion of the Selected Process Steps

In Table 4-1, a reference is made to the process stations described in our proposal of work to be carried out under this contract. In this proposal, a description of equipment used at each station was given along with estimated production rates and manpower requirements. It was decided to omit this information in discussing the manufacturing steps in the present report since preliminary information could be gathered from the proposal and actual data about the equipment used and the performance rates will be included in the final report.

As shown in Table 4-1, some additional steps have been added to the sequence described in the proposal. These additions are mainly for more frequent inspection and/or touch up steps which were not explicitly called out in the proposal. Inclusion of these additional steps is deemed necessary for a better in-process control and for added reliability of the product. Steps 6, 23, 24, 25 and 29 were included after investigation proved that these steps improved the processes and resulted in parts with more desirable characteristics. Further process investigations are continuing and, based on results of these investigations, some additional changes will be made in the process sequence.

4.1.5 Comments on the Selected Process Steps

Brief comments on the reasons for the selection of particular steps are given below:

Step 1. Incoming Material Inspection

It is imperative that materials of uniform quality which conform to exact specifications are used in the manufacture of Multilayered Wiring. Details of such testing procedures and tentative specifications are given in Section 4.4

Step 2. Shear Material

The thin base laminate cannot be sawed. Only shearing can be used to cut the received laminate sheets into the sizes required for production.

Step 3. Greaseless Buff and Clean Copper Surface

For successful photoprinting, an extremely clean and greaseless surface is required; otherwise the emulsion will not coat the surface of the copper uniformly. Various cleaning methods of the copper surface were tried, such as pumice brushing, sanding, chemical cleaning, etc. and rejected for a number of reasons. Only greaseless buffing followed by detergent scrubbing was found to produce a satisfactory surface for subsequent emulsion coating.

Step 4. Photoprint with Kodak Photo Resist

This step consists of coating the copper with a light sensitive emulsion, drying the emulsion in a whirler, exposing the coated surface to light through a negative glass, developing, dyeing and removing the unexposed emulsion. For the thin flexible panels, special tooling has been devised to facilitate the panel handling in all of these sequences.

Step 5. Inspect and Touch-up

After drying in air or an infra-red oven, each panel must be checked for any pin holes or imperfections in the printed pattern. Such defects must be corrected by hand touch-up.

Step 6. Bake

The panels should be baked to improve the etching resistance properties of the developed emulsion.

Step 7. Spray Etch

The panels are etched in a spray etcher using ammonium persulfate etchant. This method of etching has been found to be sufficiently accurate for the specified requirements. It was found that the loss in the width of the conductors during spray etching, as measured from the original artwork, is about equivalent to the thickness of the copper foil. In order to obtain a specified conductor width after etching, the artwork can be compensated for the predicted loss. The use of the splash etching technique produces a somewhat smaller loss in conductor width but is about five times more costly. In the view of such costs, it is felt that the insignificant improvement in line width preservation does not warrant the use of splash etching for the manufacture of the required parts.

Step 8. Rinse

The rinsing operation is necessary to insure that all residues and salts formed during etching are removed from the individual layer material. A rinse in hot water followed by an hour-long storage in running water has produced parts with satisfactory electrical characteristics.

Step 9. Remove Kodak Photo Resist

In this step, the etch resist coating is removed from the circuitry exposing the copper. It was determined that the most economical method of resist removal was the use of chemical strippers followed by light brushing and rinsing.

Step 10. Inspect

Each layer must be inspected after etching to determine the quality of the circuitry. All layers where conductors are either over-etched or undercut or have pinholes, nicks or breaks which effectively reduce the conductor area below the specified minimum will be rejected at this point.

Step 11. Drill Tool Holes Optically

In order to position individual layers in punching dies or laminating fixtures with the required accuracy, each layer has, on the perimeter, a number of "bullseyes" which are printed and etched simultaneously with the pattern. The tooling holes are drilled in each layer using an optical drilling machine accurate to $\pm$ .002".

Step 12. Punch Clearance Holes in Individual Layers

After the above operation, the clearance holes on all layers are punched out in a special die. Each layer has clearance holes punched in different locations, but since the location of each hole is on a standard grid for all layers of the same part, a single special die can be devised for the punching of clearance holes on all the layers which will compose one multilayer board.

Step 13. <u>Clean</u>

The punched out holes must be cleaned to remove debris left after the punching operation and the surface must be prepared for the subsequent screening of solder mask. A simple brushing with detergent and a running water rinse can efficiently accomplish this task.

Step 14. <u>Inspect</u>

All layers are inspected at this point for the quality of hole registration and cleanliness of the surface.

Step 15. <u>Apply Solder Mask</u>

A solder mask to prevent solder adhesion to the conductors on each layer must be applied by a regular screening process. In this case, the registration problems are less critical and the screening method is sufficient. This solder mask will be an epoxy type compound and will not be removed from the surface of the board prior to lamination.

Step 16. <u>Inspect and Touch-up</u>

After screening, each layer will be inspected and observed imperfections in the solder mask will be touched up.

Step 17. <u>Bake</u>

The Solder Mask must be hardened by baking at 250°F. for at least 2 hours.

Step 18. <u>Apply Flux to Layers</u>

The parts will be prepared for soldering by applying a rosin type flux on the surface of the layers.

Step 19. <u>Air Dry</u>

For best performance, the flux must be air dried before soldering.

Step 20. <u>Form Solder Fillets on Pads of Each Layer</u>

The layers will be placed in a special fixture and then floated on the surface of a solder pot. In this manner, solder fillets will be formed on all unmasked pads.

Step 21. Ultrasonic Cleaning

The layers will be ultrasonically cleaned using suitable solvents to remove all flux from the boards.

Step 22. Inspect and Touch-up

All layers will be inspected for proper fillet formation and defective fillets will be touched up by hand soldering.

Step 23. Light Vapor Blast

In order to roughen the surface of the layers for better adhesion in lamination, a light vapor blasting with an abrasive slurry will be performed.

Step 24. Rinse

The layers will be rinsed in running water after Step 23 to remove any residue of abrasive particles.

Step 25. Oven Dry

In order to insure complete dryness of the layers before lamination, they will be baked in a 250°F. oven for at least 1/2 hour and then stored in a humidity controlled room.

Step 26. Cut to Size & Drill Mounting Holes in Adhesive & Backing Material

Layers of adhesive and backing material used for lamination will be cut to size and mounting holes will be drilled in the same locations as on the circuit layers, using a special template.

Step 27. Lay up and Laminate

The circuit and adhesive layers will be stacked in the proper sequence in a special laminating fixture. Proper registry between layers will be insured by placing each layer on pins placed on the perimeter of the laminating fixture. These pins exactly correspond to the drilled mounting holes on the individual layers. Then, the laminating fixture will be closed and transferred from the humidity controlled room (where previous operations have been carried out) to the laminating press where the circuits will be laminated.

Step 28. Trim Flash

After lamination, the laminated part will be removed from the fixture and the flash formed around the edges of the part due to the flow of the adhesive will be trimmed.

Step 29. Postcure

To insure better performance of the finished multilayer circuits and to improve their electrical characteristics, a postcure cycle has been found to be beneficial. This postcure can be performed in a high temperature oven since no pressure is required for the operation.

Step 30. Drill Component Lead Holes

The laminated circuits will be placed in registry on the table of an automatic 10-spindle drilling machine and the component holes will be drilled in each part.

Step 31. Deburr

During the drilling of the component holes, occasional burrs appear on the underside of the part. Since proper height control is needed for the next operation, these burrs must be removed by hand-sanding the copper surface.

Step 32. Spot Face Terminal Areas

Using the drilled holes as a guide, the adhesive, which filled the clearance holes during lamination, will be removed by a facing tool. At the moment, the exact tool shape or the equipment which will be used for this operation has not been determined. Various approaches for this operation are being investigated.

The most difficult problem in this area is exact control of the depth of tool penetration to achieve a complete facing of the pads on various layers.

Step 33. Clean Holes with Steam Knife

After the facing operation, loose particles will be left inside the clearance holes. To remove them and clean the exposed pads, a cleaning by a high pressure steam knife is introduced.

Step 34. Rough Cut

Cleaned parts are then sheared to about 1/8" of the final layer size.

Step 35. Rout to the Finish Size and Clean Edges

The shearing or sawing of the laminated epoxy boards will produce rough edges. The best method of producing smooth, clean edges on epoxy fiberglass boards is routing. For this operation, the parts are pinned on a special jig made to the exact size of the boards and the rough edges are cut away by a router bit rotating at very high speeds.

Step 35. Final Inspection, Mechanical

The completed parts are sent to the final inspection area where their conformance to the required mechanical dimensions is checked.

Step 37. Final Inspection, Electrical

In multilayer circuits, the electrical interconnections cannot be checked visually as is the case with single or double sided circuits. Additional electrical checks must be performed before the parts are shipped to insure that they fulfill all of the specified requirements. Also, in this step, environmental checks on a sampling basis will be performed to insure compliance of a given lot of parts to the entire specification.

Step 38. Package and Ship

The parts will be packaged in sealed protective bags, properly identified, and shipped as per prevalent instructions.

4.1.6 Artwork Preparation

The artwork for each layer of the Test Patterns specified in SCL-7503B/1 for Subminiature Boards and SCL-7503B/2 for Ultraminiature Boards has been prepared. Prints of these layers are attached to this report as are prints of a composite pattern for each type of board. The patterns are made with dimensional changes as requested in TAR-899-1 and 899-2. These changes were needed to make the patterns uniform and to correct some dimensioning mistakes in the original sketches of SCL-7503B Specifications.

The conductor widths on this artwork have been compensated for the expected loss in the etching operation to insure that the fabricated parts will have lines and spacings within the specified tolerances.

As can be seen from the prints, each individual test pattern is separated from the adjoining patterns by a small spacing. This spacing is required to facilitate cutting individual patterns for mounting during environmental testing. Each individual pattern has the dimensions as specified in SCL-7503 but the overall size of the composite board is now somewhat larger.

4.1.7 Design of Prototype Tooling

The tooling required for the production of Engineering Samples has been designed and fabricated. Essentially, it consists of the following items:

a) A laminating fixture in which individual layers are pinned in proper registry and laminated.

b) A drilling jig. For the production of Engineering Samples, it was uneconomical to build a complex die for the punching of clearance holes on individual layers. The clearance holes on the layers for preliminary Engineering Samples will be drilled out. The drilling jig for this purpose has all the holes for all layers. They are used selectively as required by the amount and location of the clearance holes on each particular layer.

   The same drill jig is used for predrilling of the mounting holes in the adhesive and backing material.

c) A router plate for routing the parts to size.

d) Screens for screening of solder mask resist.

   This tooling is sufficient to produce the required Engineering Samples. This tooling is not in all cases exactly the same as that which will be used for the pilot run (as in the case of punching die), but the difference in tooling will have little effect on the manufactured parts and their characteristics.

4.2 Work on Phases II and III (Production and Manufacturing Engineering)

The work on Phases II and III was not scheduled to start in the first quarter. (See Figure 1-1) Only the establishment of supply sources was supposed to be carried out in this period. However, it was decided to postpone this operation until more complete information about the performance of base materials is collected. Based on such information, an Approved Vendors List will be prepared. See Sections 4.4.3 and 4.4.4 for details.

4.3 Work on Phase IV Quality Assurance

4.3.1 General Comments

During the reported period, only work on the first task of this phase was scheduled and it is being carried out. This task is not yet completed, since more samples from additional vendors have been ordered for evaluation and further correlation of obtained data is required before the final specifications can be issued.

It is estimated that this task is about 70% completed and final completion is rescheduled toward the end of the second quarter.

4.4 Specifications for Thin Base Laminate

4.4.1 Objectives:

The objective of this task is to develop a specification for thin epoxy fiberglass G-10 base laminates which will insure uniform quality and the compatibility of received materials with subsequent processing.

4.4.2 Background

There are various military and commercial specifications covering copper clad epoxy fiberglass laminates used for the manufacture of printed circuits. The manufacture of multilayer boards requires, however, some additional and peculiar requirements not applicable to regular types of laminates. At the present time, there are no specifications for such materials. In order to evaluate materials produced specifically for multilayer printed wiring applications, uniform test standards must be available for the comparison of products of various vendors and to insure that purchased base laminate material will be satisfactory and adequate for the manufacture of layered printed wiring.

4.4.3 Specification for Thin Base Laminate Material

Attached to this report is a Tentative Specification for Thin Glass Epoxy Laminate. This specification contains all the requirements which have been deemed necessary for a good base laminate product for Layered Printed Wiring. Also, the exact test procedures for testing of various parameters of such materials are described. However, in some cases there is no information given for acceptable or non-acceptable ranges of values obtained from these tests. At the present time the tests on thin epoxy glass materials, according to this specification, are being run in our Quality Control Laboratory to establish the range of values obtained from the materials of various vendors. After these tests, multilayer samples will be prepared from the remainder of the lots submitted for testing and environmental tests will be performed on these composite boards to insure their compatibility with existing requirements for multilayered boards.

Based on the results of tests on composite boards, the acceptable values for the individual layer base material will be determined and included into the tentative specification. This task is expected to be completed by the end of the second quarter of the subject contract.

The complete specification will be distributed to the vendors in order to familiarize them with the test methods and requirements for acceptable thin epoxy glass base laminate.

4.4.4 Approved Vendor List

When the results of preliminary qualification tests, as described above, are completed, a tentative Approved Vendors List will be compiled. Since the quantity of base laminate required for the manufacture of 60 multilayer boards per 8 hour shift is substantial, a survey of vendors' facilities will be made. In this survey, vendors will have to demonstrate the ability to produce the required quantity of thin base laminates and to sustain such a production rate without any decrease in quality of the product.

After this survey is completed the final Approved Vendors List will be made. This list will be periodically reviewed when additional vendors qualify for inclusion.

4.4.5 Testing of Base Laminate Samples

Samples of thin epoxy fiberglass laminates have been ordered from all known manufacturers of such materials. The received sample sheets have been evaluated according to the requirements outlined in the preliminary specifications:

The following materials were evaluated:

TABLE 4-2 Samples Tested

SAMPLE #	THICKNESS			COPPER FOIL
1499	.005"	Overall thickness		1 oz 2 sides
1500	.008"	"	"	2 oz 2 sides
1466	.010"	"	"	2 oz 2 sides
1467	.008"	"	"	2 oz 2 sides
1526	.004"	Base	"	2 oz 2 sides
1527	.008"	"	"	2 oz 2 sides
1528	.012"	"	"	2 oz 2 sides
1469	.005"	"	"	2 oz 2 sides
1559	.016"	Overall	"	2 oz 2 sides
1473	.008"	Base	"	1 oz 2 sides
1472	.003"	"	"	2 oz 2 sides
1471	.002"	"	"	2 oz 2 sides
1470	.001"	"	"	2 oz 2 sides
1498	.005"	"	"	2 oz 2 sides
1497	.012"	Overall	"	2 oz 2 sides
1468	.008"	"	"	1 oz 2 sides
1560	.008"	Base	"	2 oz 2 sides

Data sheets with the results of these tests are attached to the report. The test procedures for each measurement are given in the tentative specification. The paragraph numbers for each particular test on the attached data sheets do not correspond to the paragraph numbers of the tentative specification so only the title of the test should be used for identification. The numbers in the "conforms" column represent the number of samples used for the test which passed that particular requirement.

SECTION 5

CONCLUSIONS

1. After thorough investigation of available processes and techniques, a tentative process sequence has been selected for the manufacture of Miniaturized Layered Wiring Boards by the "clearance hole" method of construction.

2. Most of the selected manufacturing steps have been tried out to prove that each step is definitely needed to make the entire process more reliable or more economically efficient. Also, adaptability of each process for high rate production was studied before inclusion into the sequence.

3. A few manufacturing steps are still under investigation and this investigation is expected to be completed in the next quarter.

4. Artwork in accordance with the requirements of SCL 7503B/1 and SCL 7503B/w has been prepared.

5. Tooling needed for the production of preliminary Engineering samples has been designed and fabricated.

6. A tentative specification for thin epoxy fiberglass material has been prepared. In this document, the required qualities of the material are specified and the procedures for qualification testing of the submitted samples are described. The final version of this specification is expected to be ready in the second quarter.

7. Qualification testing of numerous submitted samples has been carried out and the results are described in this report.

SECTION 6

FUTURE WORK

In the second quarter of the subject contract, the following work is scheduled to be carried out:

1. Work in Phase I.

   a) Production and testing of preliminary test samples.

   b) Re-evaluation of some steps of the selected process sequence to arrive at the most reliable and efficient manufacturing procedure.

2. Work in Phase II

   a) Process standards to be issued.

   b) Process rates to be established.

   c) Vendor facilities survey to be completed.

3. Work in Phase III

   a) An analysis of production equipment will be made to ascertain that it will be adequate to sustain the required production role.

   b) Manpower analysis and allocation will be completed.

   c) Design of the tooling for the preproduction run will be started.

4. Work on Phase IV

   a) Results of incoming material testing will be evaluated to determine the acceptable ranges of various measured characteristics.

   b) Final specifications for thin base laminate material will be prepared.

   c) Testing procedure and equipment for testing of Engineering Samples will be prepared and approved.

d) Work will be started on in-process quality control specifications.

It is expected that in the second quarter, work on Phase I will be 90% completed; on Phases II and III - 30% completed and on Phase IV - 40% completed. These rates will be in exact agreement with the proposed schedule of work.

SECTION 7

IDENTIFICATION OF KEY TECHNICAL PERSONNEL

During the first quarter the following persons took part in the work covered by this report:

TABLE 7-1

Key Technical Personnel

NAME	TITLE	MAN HOURS
G. Messner	Project Manager	61
R. McCaw	Senior Engineer	86
M. Pulaszek	Production Engineer	166
W. A. Baldwin	Quality Engineer	25
L. A. Gunsaulus	Quality Assurance Manager	15
	Technicians	227

A short resume of each of the Key Personnel who worked on this project is attached.

PROJECT MANAGER - G. Messner

Mr. Messner is Product Manager for the Encapsulayer Division and Printed Switch Division at Photocircuits Corporation. He is responsible for complete administration of both divisions and reports to the company Steering Committee.

Mr. Messner studied Pre-Engineering at Brooklyn College and received a Bachelor of Electric Engineering degree from the City College of New York.

From 1953 to 1957 Mr. Messner was Manager of the Testing and Evaluation Departments of the Yardney Electric Corporation, New York, N. Y. Mr. Messner was a Project Engineer in the Research and Development Department at Yardney from 1957 to 1960.

Mr. Messner has been with Photocircuits since 1960.

SENIOR ENGINEER - Robert K. McCaw

In his present capacity at Photocircuits as production engineer, Mr. McCaw is responsible for the evaluation and improvement of production processes and production machinery. He has been associated with the design and responsible for construction of the numerically controlled drilling equipment designed at Photocircuits for volume production of printed circuits.

Mr. McCaw received his bachelor degree in Mechanical Engineering from the College of the City of New York in 1953. He has completed additional studies in the fields of servo-mechanisms and industrial electrical engineering.

From 1955 through 1960 he was employed at the Grumman Aircraft Engineering Corporation as a manufacturing engineer and was responsible for special tools and controls for automatic riveting machinery and for the investigation and evaluation of automatic production techniques. He has designed special tools and machines for such purposes.

From 1953 to 1955 he was a specialist with a Technical Service Unit at the U. S. Army Signal Corps Research Laboratories, Fort Monmouth, N. J. Prior to that he was employed as a test engineer at the Bendix Corporation's plant in Teterboro, N. J. He has been employed at Photocircuits since 1960.

PRODUCTION ENGINEER - M. Paluszek

As process engineer, Mr. Paluszek is responsible for evaluation and improvement of production processes for the multilayer program at Photocircuits.

Mr. Paluszek completed his studies at the College of The City of New York in Chemical Engineering, supplementing this with additional work in Plastics Technology at the Plastics Industries Institute.

From 1947 to 1955 he was with the Printing Ink Division of the Inter-chemical Corporation as group leader of the Specialty Coatings Laboratory in Elizabeth, N. J.

He was Development and Production Engineer with the Spray lat Corporation in the Bronx, N. Y., working on the development of a strippable plastic coatings used by the services and industry for the temporary protection of metals and plastics during fabrication processes.

From 1960 to 1962 Mr. Paluszek was Plant Supervisor of the Haeuser Shellac Corporation of Brooklyn, acting also in the capacity of Chief Engineer in the design and relocation of their new installation.

He enlisted into the Signal Corps in 1942, receiving his electronics training at Manhattan College and Fort Monmouth, N. J. He was then transferred to the Psychological Warfare Unit of the U. S. Army, where he attended the School of Foreign Service at Georgetown University.

Mr. Paluszek joined Photocircuits in July of 1962.

QUALITY ENGINEER - W. A. Baldwin

Mr. Baldwin is presently a Quality Engineer at Photocircuits Corporation. He is responsible for investigation and testing of processes and materials used in manufacturing. He employs this information to establish reliability and quality assurance of the final product.

Mr. Baldwin was granted the degree of B.S. in Industrial Engineering from Hofstra College in 1951. He also is a graduate of the Electrician's Mate School at Montgomery Junior College, Takoma Park, Maryland.

From 1951 to 1955, Mr. Baldwin was an Electrician 2/c with the USN. He was responsible for the maintenance of shipboard electrical systems.

Mr. Baldwin was with Hazeltine Corporation of Little Neck, N. Y., from 1959 to 1960. He was a Production Engineer responsible for scheduling, methodizing and quoting.

Mr. Baldwin has been with Photocircuits since 1960.

QUALITY ASSURANCE MANAGER - L. A. Gunsaulus

As Quality Assurance Manager of Photocircuits Corporation, Mr. Gunsaulus supervises Quality Control, Quality Assurance and Quality Engineering. Mr. Gunsaulus was Chairman of the Dimensional Tolerance Committee of the Institute of Printed Circuits, a member of the Electronics Industries Association Sub-committee on Printed Wiring and the Vice-Chairman of the Institute of Printed Circuits - NEMA Joint Raw Materials Committee.

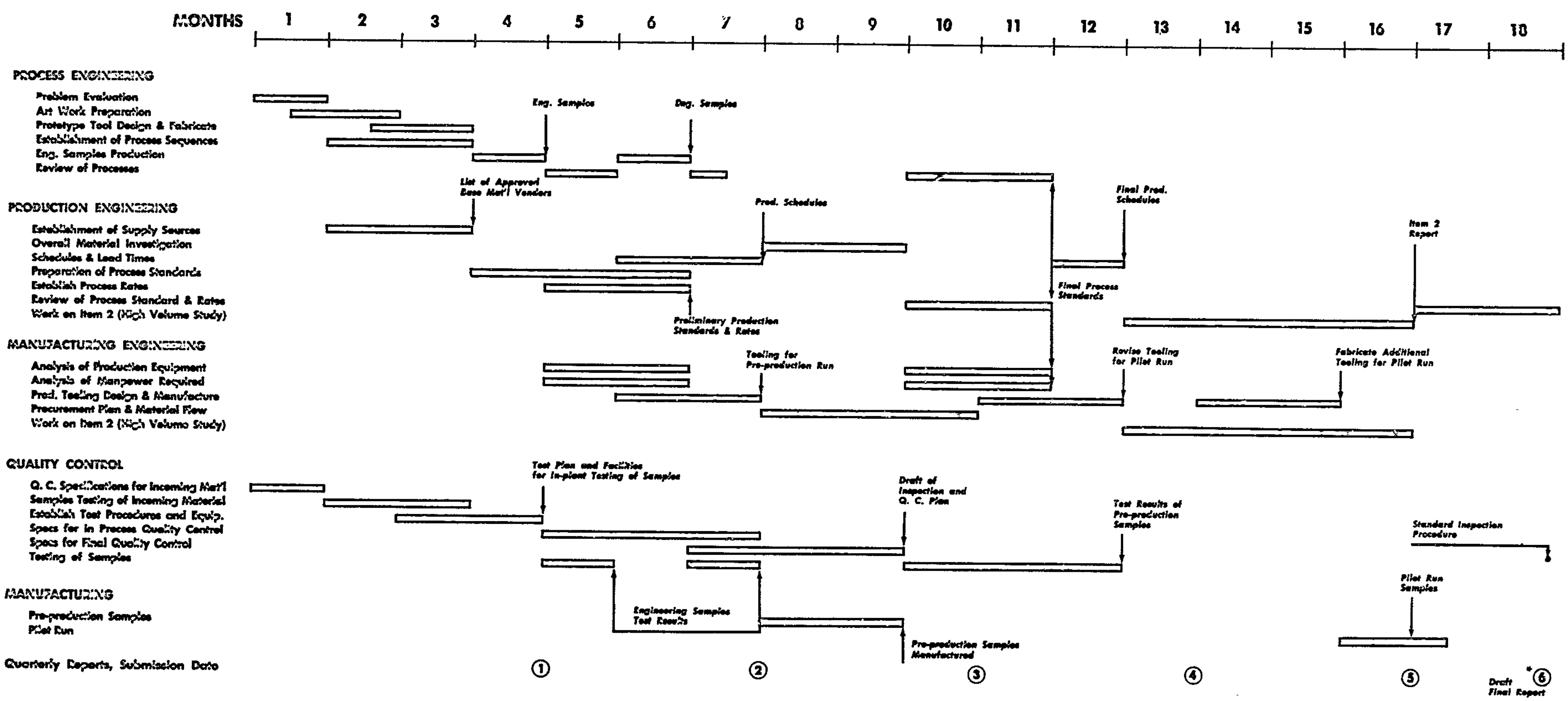
Mr. Gunsaulus studied Pre-Engineering at Syracuse and Rutgers Universities and Education at Brooklyn College.

In 1949, Mr. Gunsaulus was an Analytical Chemist for the Aircraft Plating Company of Brooklyn, N. Y. Mr. Gunsaulus was Production Supervisor for the Leviton Manufacturing Company of Brooklyn from 1952 to 1954.

Mr. Gunsaulus has been with Photocircuits since 1954.

SECTION 8

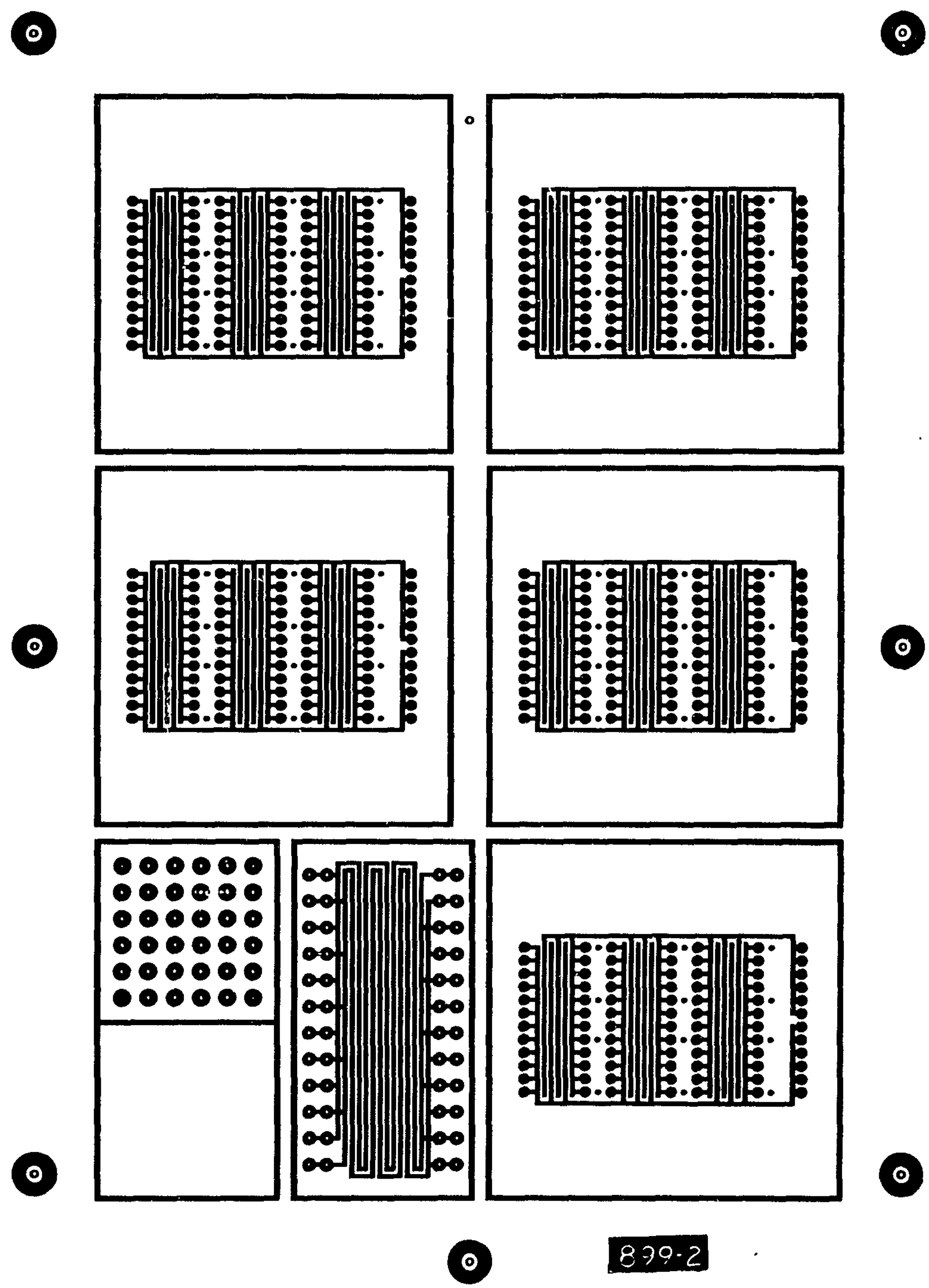
REFERENCES



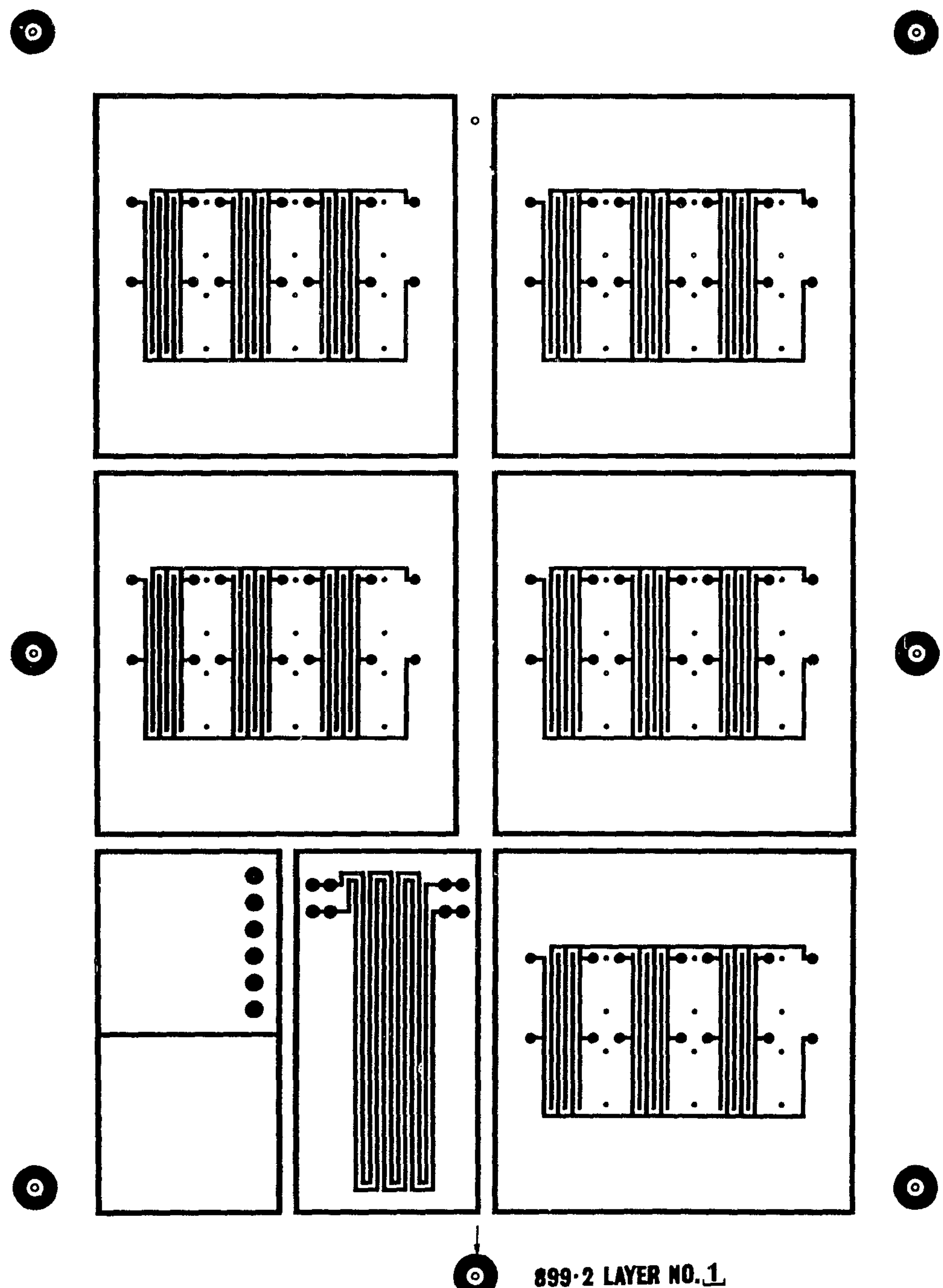
*QQ of Materials and Manufacturing Operation Manual

Figure I-1 PROPOSED WORK SCHEDULE

8.2 Prints of the Artwork for Test Patterns SCL-7503B/1 and SCL-7503B/2



899-2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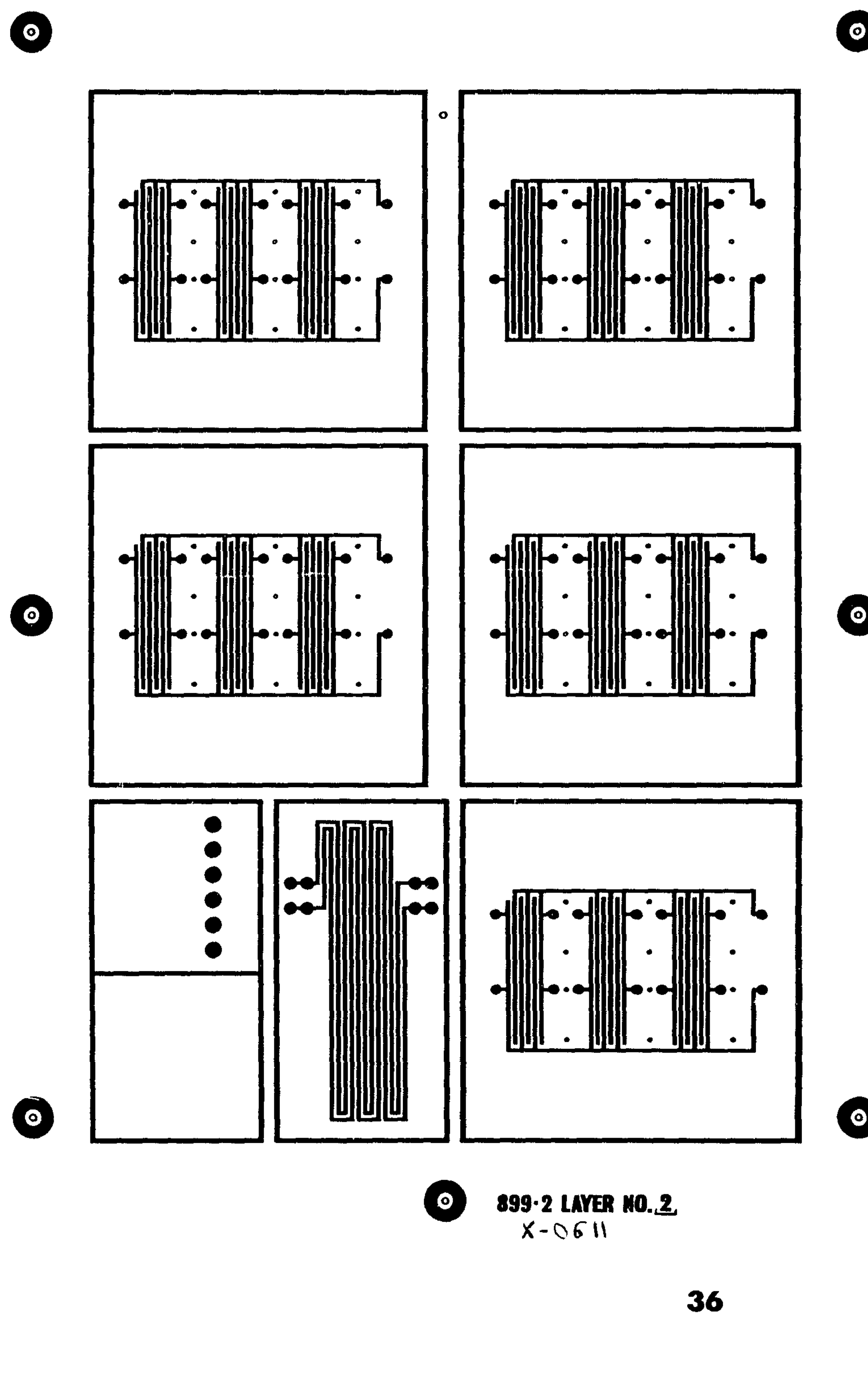

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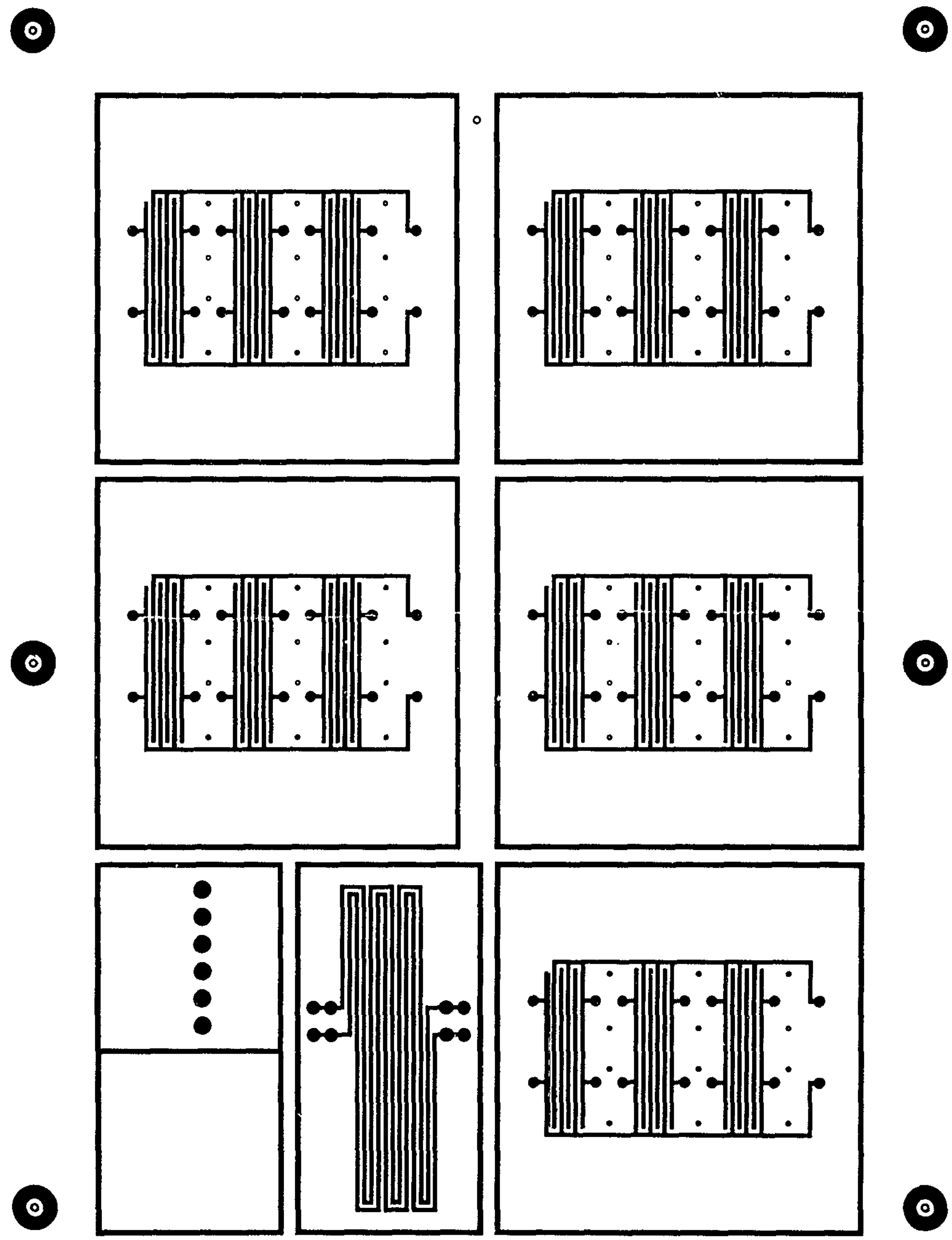

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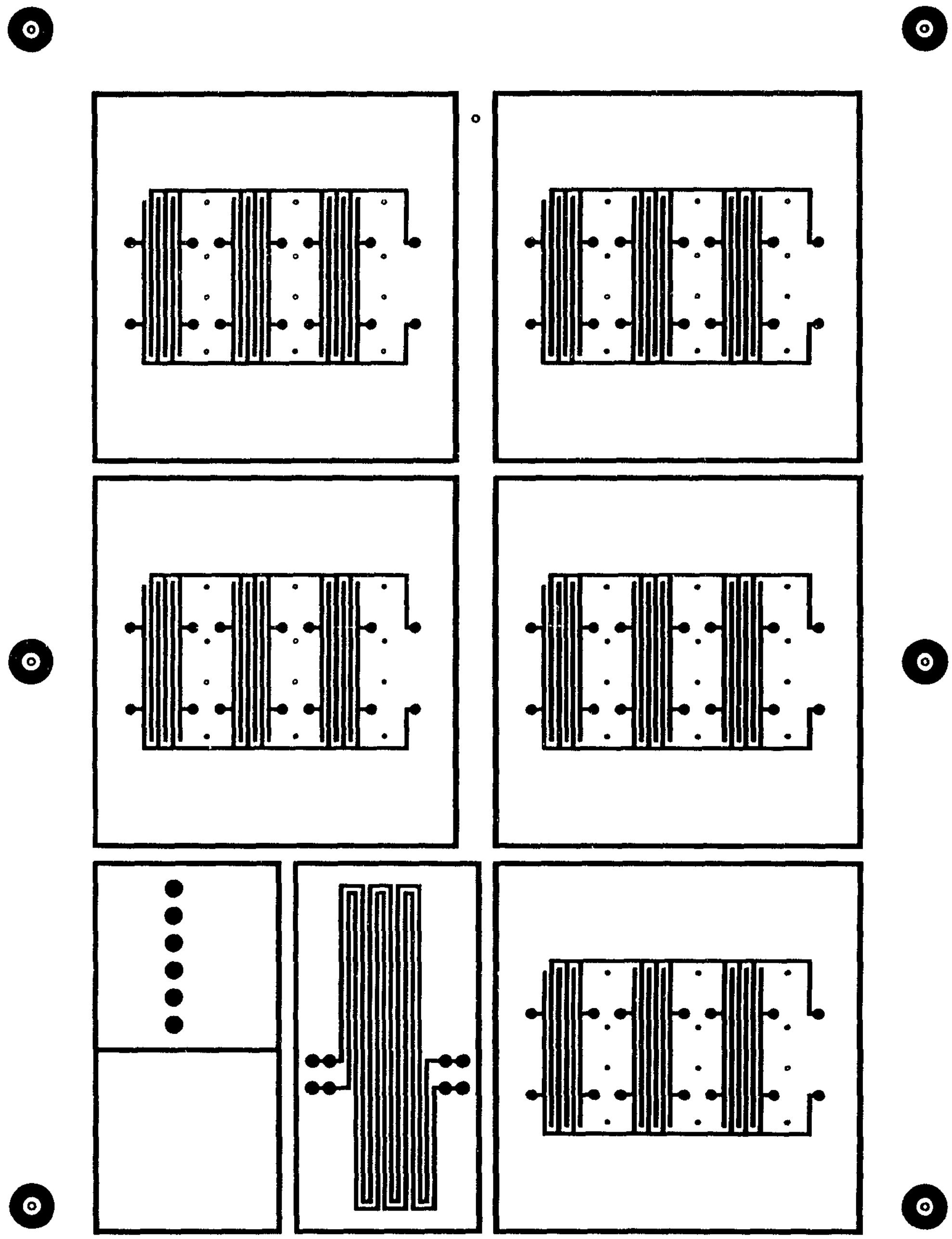

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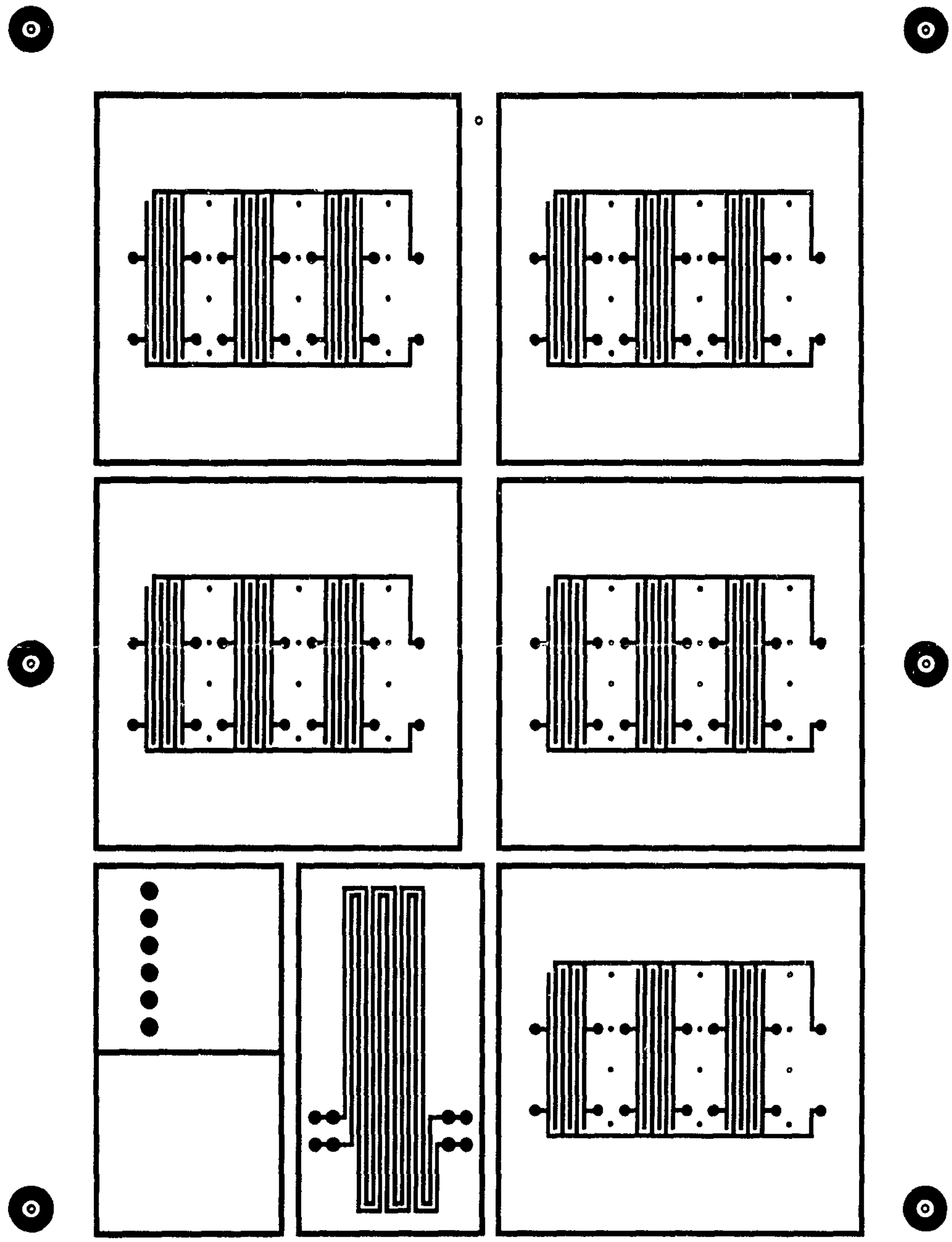

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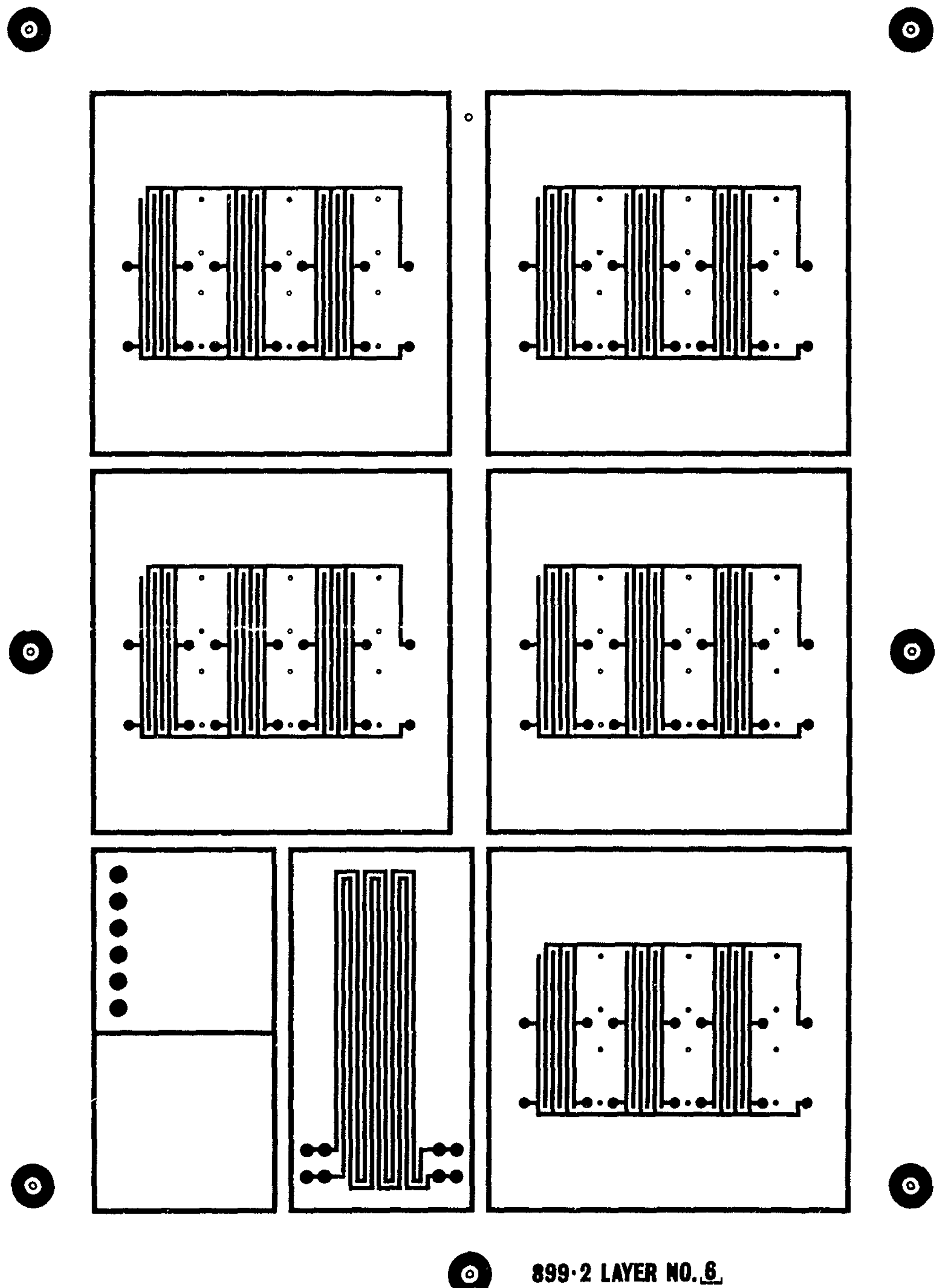

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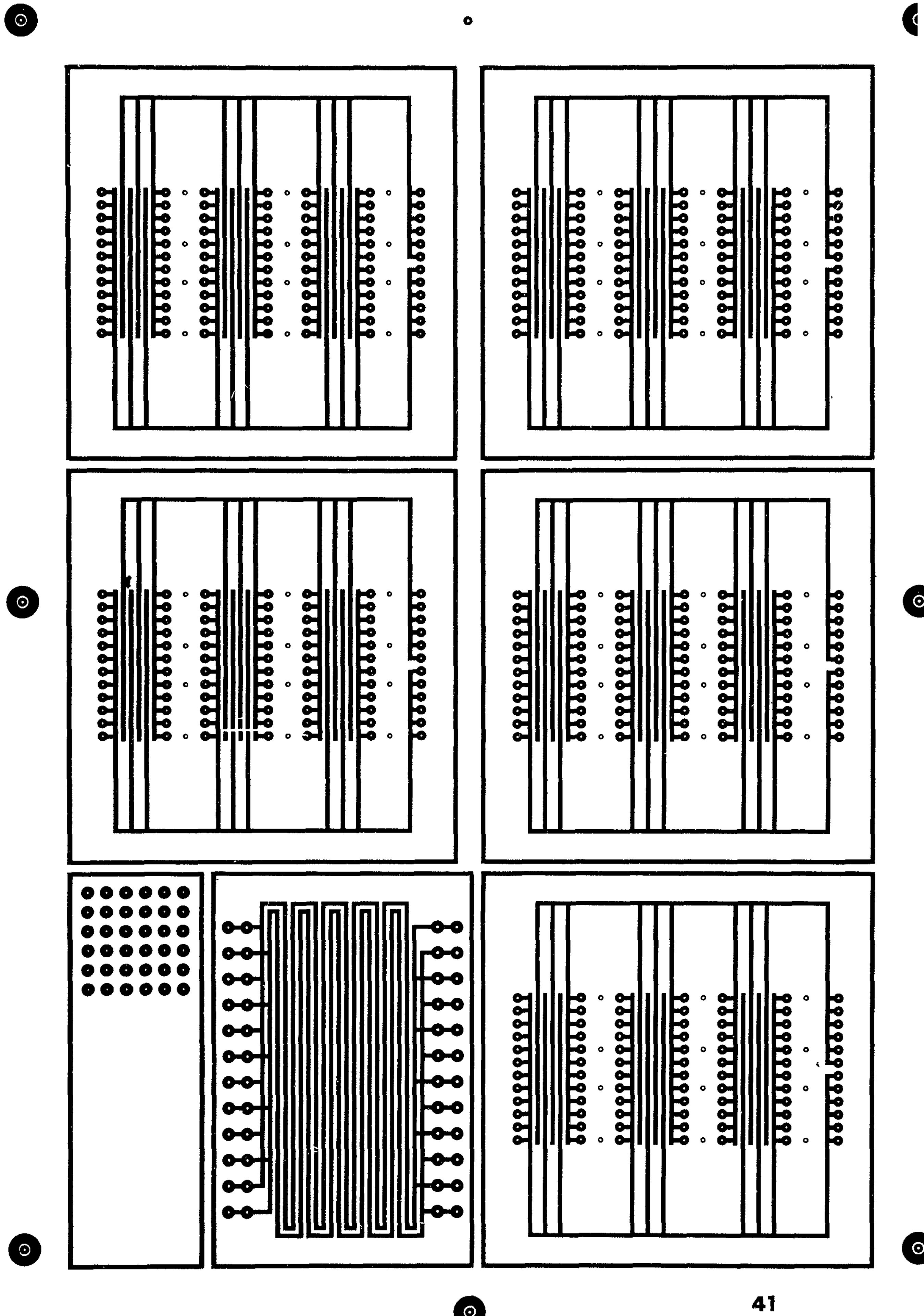

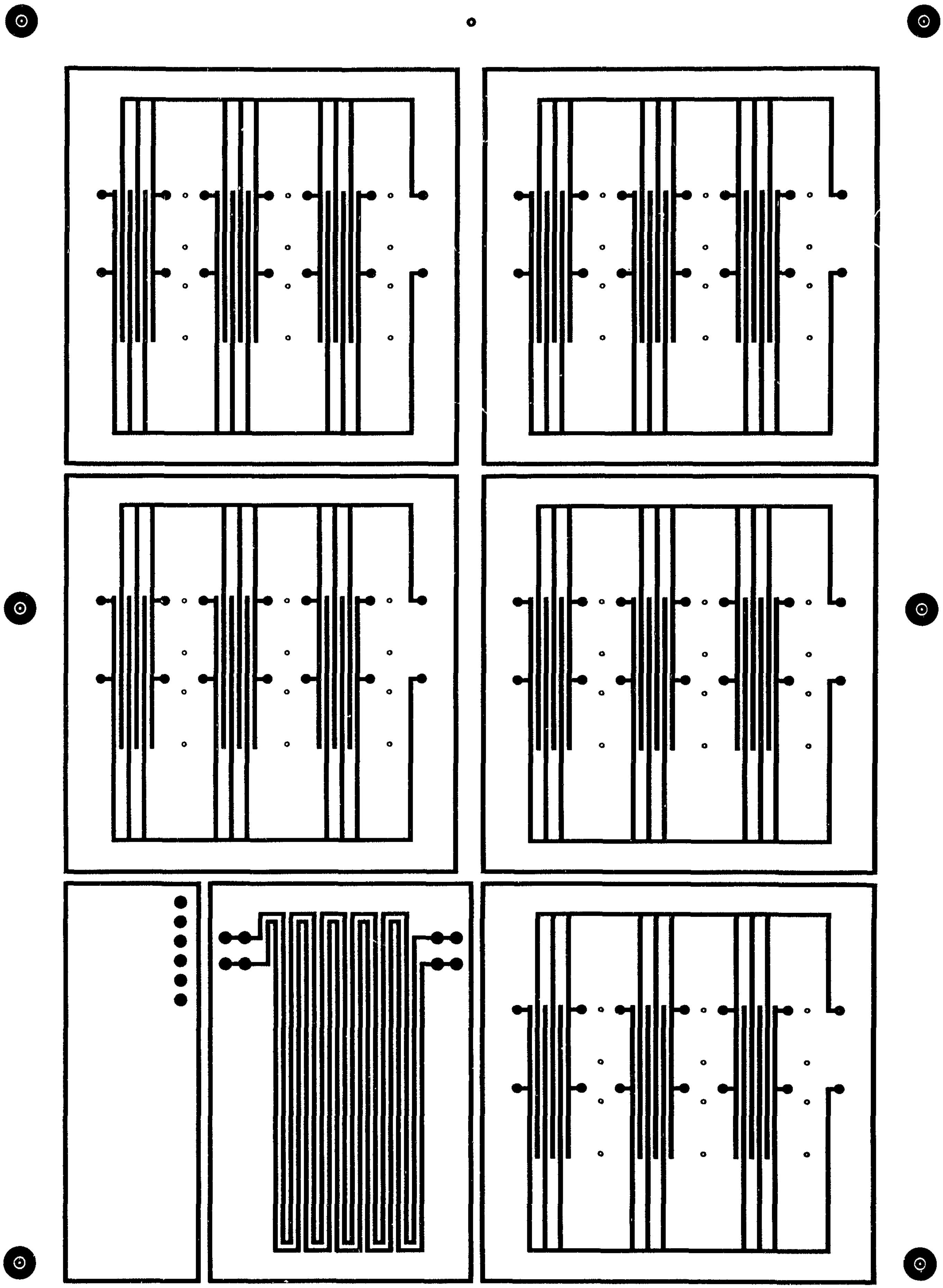

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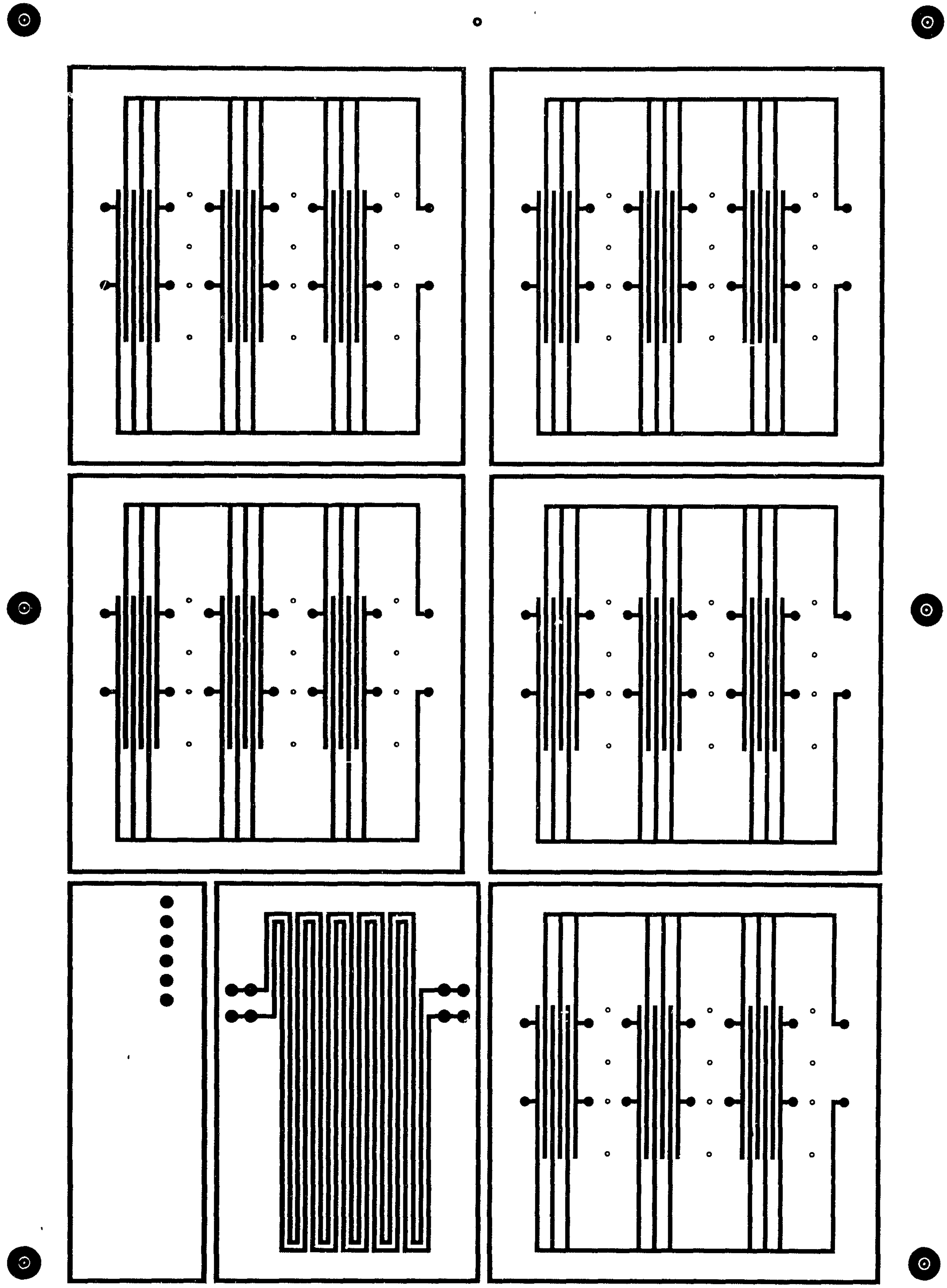

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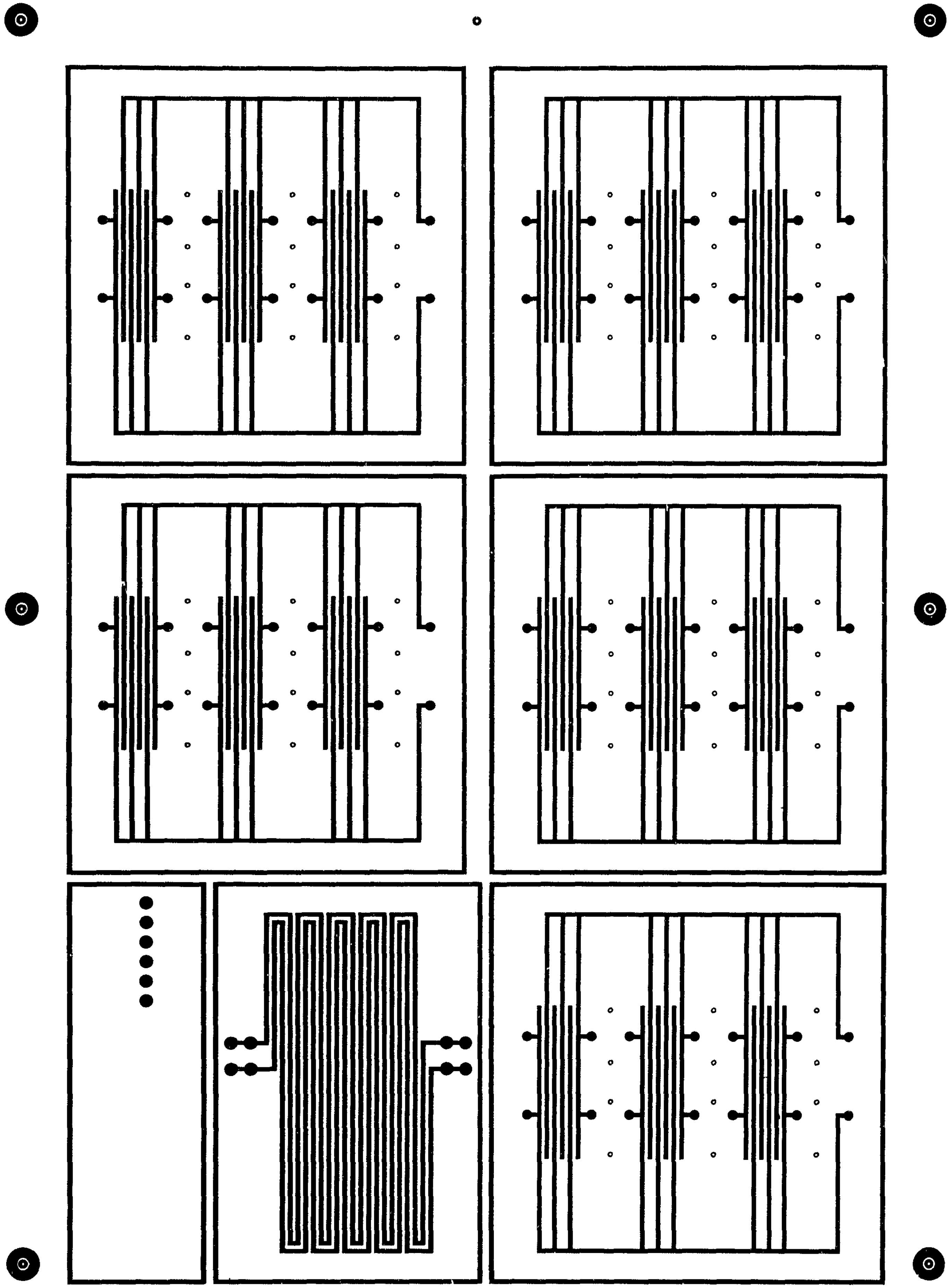

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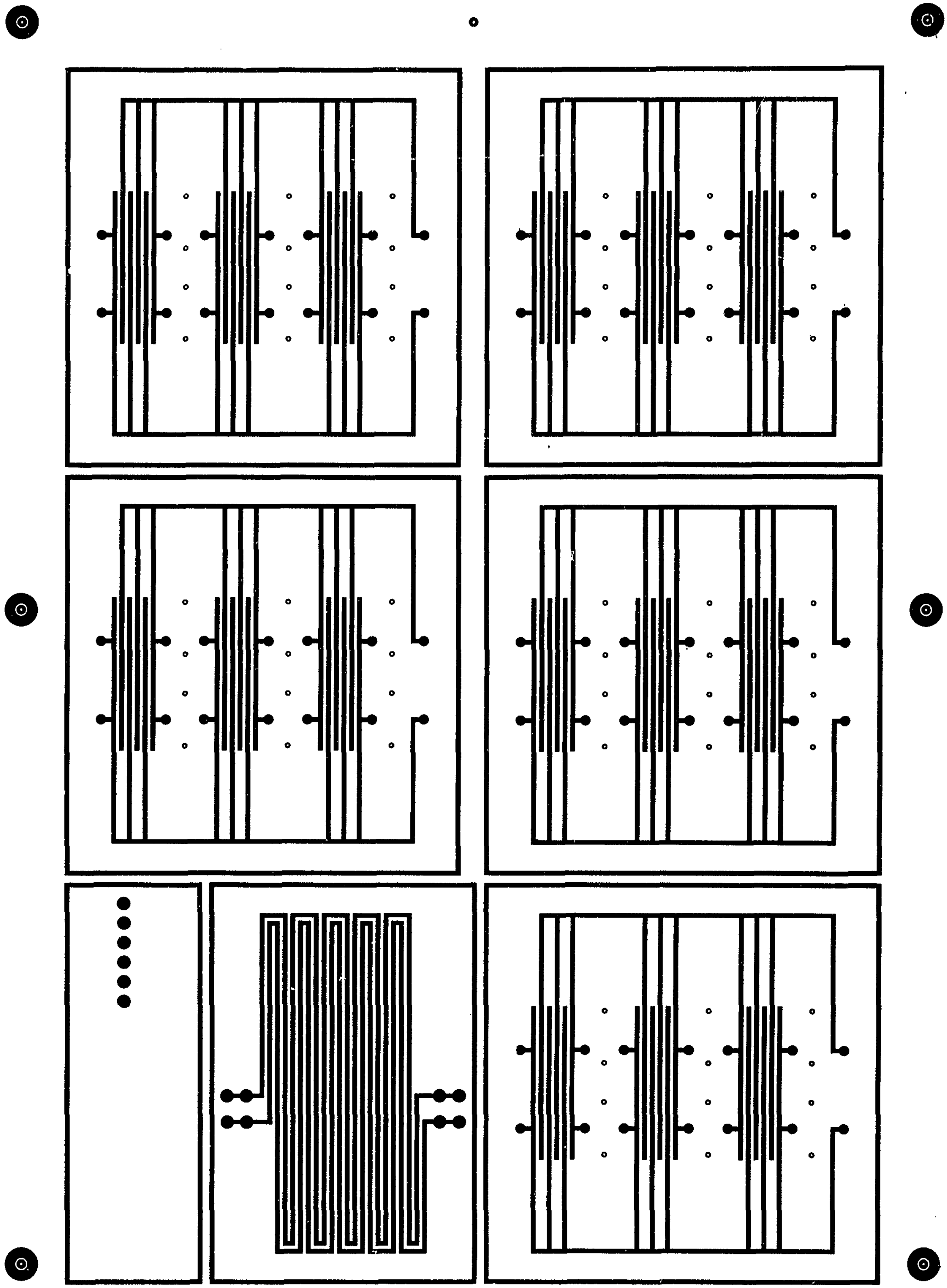

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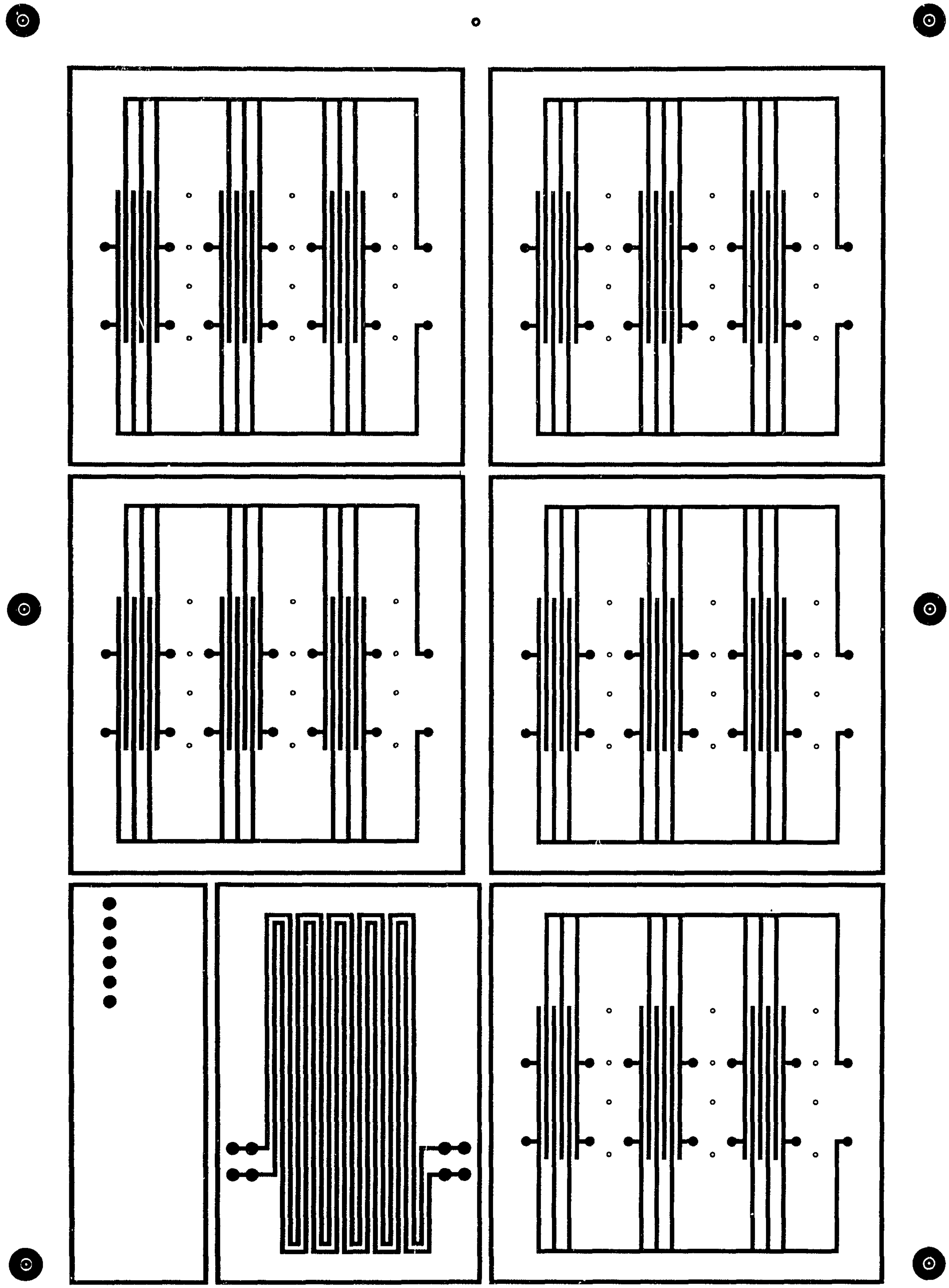

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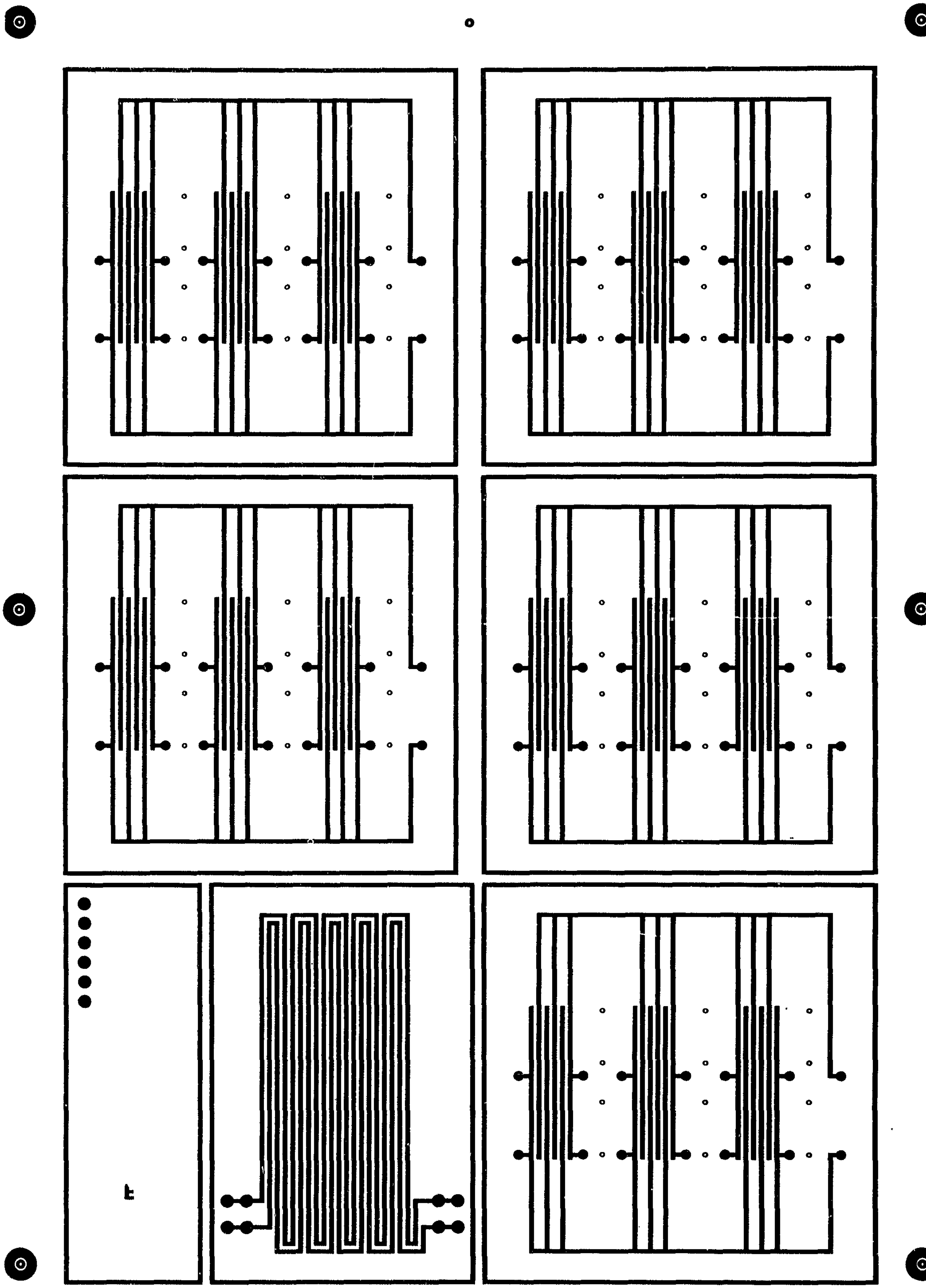

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SECTION 8.3

TENTATIVE SPECIFICATION FOR THIN BASE LAMINATES

TYPE OF INFO: SPECIFICATION

SUBJECT: LAMINATES, COPPER CLAD, THIN GLASS BASE EPOXY

1.0 SCOPE

This specification covers the requirements and acceptance criteria for copper clad laminates in thicknesses of 1/64" and less, to be used primarily for the fabrication of printed wiring and/or Multi-layer Printed Wiring Boards.

2.0 TYPE DESIGNATION

Two basic applications for thin base materials are covered in this specification and the designation shall be as follows:

2.1 Type I - Thin materials for printed wiring board use.

2.2 Type II - Thin materials for multilayer applications.

3.0 RESIN DESIGNATION

The resins used for the composite material shall be of the following types:

3.1 Resin A - G-10 grade epoxy

3.2 Resin B - G-11 grade epoxy

4.0 APPLICABLE DOCUMENTS

The following specifications and standards of the issue in effect at placement of order date shall form a part of this specification to the extent specified herein:

Mil-STD-105	Sampling Procedures
Mil-P-13949	Plastic Sheet Laminated - Copper Clad
ASTM Part 9	American Society for Testing Materials
Federal STD LP-406	Plastics, Organic, General Specification
Federal Specs QQ-S-571	Solder & Solder Alloys

Test Methods

Mil-C-14550	Copper Plating (electrodeposited)
Mil-F-14256	Flux, Soldering, Liquid (resin base)
Mil-P-18177	Plastic Sheet Laminated, Thermo setting, Glass Fiber Base, Epoxy Resin

5.0 GENERAL REQUIREMENTS

The following general requirements apply to material of all types purchased to this specification:

5.1 Composite Material

The composite material shall consist of layers of glass cloth impregnated with the applicable type resin compound, overlaid with copper, one or both sides. The whole assembly shall be bonded together at one time and processed so as to meet requirements of this specification.

5.2 Copper Foil

The copper used shall conform to Mil-C-14550 and shall be of the electrolytic, electro-deposited type with a minimum purity of 99.5 percent. Copper thickness and tolerance shall be as follows:

1 Ounce	0.0014 + 0.0004
	- 0.0002
2 Ounce	0.0028 + 0.0007
	- 0.0003

The copper shall be free of such defects (pinholes, pits, dents, and scratches) as would adversely affect functional serviceability. The copper as supplied to this specification shall be as it is removed from the laminating press unless otherwise specified. No finishes, finishing, or cleaning shall be performed unless specifically stated on the purchase order. The finishes designated by the purchase order may be tampico brush, pumice slurry brush, "scotchbright," belt sanded, etc. In such cases the copper shall wet with water and not show any evidence of residue from the finishing operation.

5.3 Base Laminate

The base laminate on the unclad side or as etched shall be uniform in texture, finish, and color after completion of any of the tests of this specification. It is understood that excessive heat exposure may change the color of the surface resin or adhesive. The unclad side of single-sided materials shall be free of silicone or other release agents which may inhibit ink marking or the laminating properties of the base material.

5.4 Thickness

The nominal thicknesses and tolerances overall shall be as specified in Table I unless otherwise indicated in the purchase order.

TABLE I

	Glass Base
Nominal Thickness (Including Foil)	1 oz. 1 & 2 sides 2 oz. 1 & 2 sides
Up to .005	$\pm$ .001" (1 oz. copper only)
.006 - .010	$\pm$ .002"
.011 - .015	$\pm$ .003"

5.5 Warp or Twist

The clad or unclad sheets shall be reasonably flat in the "as received" condition. The warpage shall be less than .062" per linear inch using Fed. Std. LP406 method 6051.

5.6 Machineability

Each copper clad laminate shall be such that it can be sheared, drilled, punched and machined in all directions in accordance with good commercial practice without cracking, splitting, or otherwise impairing the material for printed circuit use.

5.7 Property Values

When specimens are tested as specified herein, the values obtained from a set of specimens for a specific property shall be averaged and that average shall conform to the requirements as specified in Section 7, except for solder dip, peel strength, volume resistivity, and surface resistance tests, where each specimen shall meet the specified requirements.

5.8 Lay-Up

The base material shall be composed of two or more sheets of glass weave impregnated with the designated resin, in accordance with Mil-P-18177.

5.9 Copper Treatment Residue

The base material shall not show any residue or evidence of degradation from the copper treatment or adhesive after etching in Ferric Chloride, Chromic Acid or Ammonium Persulfate.

5.10 Material Stability

There shall be no softening, swelling, or discoloration when the base material is exposed to an alkaline stripper for one minute at room temperature, then scrubbed with a soft bristled brush and hot water. The alkaline pH will not exceed pH 13.

5.11 Dimensional Stability

When the copper is etched away from the glass base, the material shall not expand more than .001"/inch in width or length of material.

5.12 Pin Holes and Stretched Weave

The individual sheets of resin-coated glass cloth that make up the laminate shall be free of pinholes and stretched or pulled weave.

6.0 METHODS OF EXAMINATION AND TEST

6.1 Solder Dip, Etched

6.1.1 Specimen Preparation

Specimens 3 x 3 by thickness shall be cut from a convenient corner of the sheet. The peel strength pattern of Figure I shall be procided by a suitable means and etched in any suitable etching solution. Rinse for one hour in cold running water to remove acid residues. This specimen to be tested for peel strength (paragraph 6.3) before and after performance of 6.1.2.

6.1.2 Test Method

Immerse specimen in flux conforming to Mil-F-14256 Type A maintained at a specific gravity of .93-.95 and allow to set a maximum of five (5) minutes. Float copper side down on a bath of 60-40 composite solder conforming to Type SN60 of QQ-S-571. The temperatures and dwell time shall be as specified in Table II for the various thicknesses.

TABLE II

Base Material Thickness without copper	Temperature	Dwell Time
.001" to .007"	475 $\pm$ 5°F.	5 sec.
.008" to .015"	500 $\pm$ 5°F.	5 sec.
.0015" to .025"	500 $\pm$ 5°F.	10 sec.

After soldering clean specimens in isopropyl alcohol (99% U.S.P.)

6.1.3 Appearance

Upon completion of the etching, soldering, and solvent exposure tests, the appearance of the processed specimens shall not be degraded. The copper foil shall not blister nor delaminate from the base laminated plastic. The adhesive or resinous material exposed on the base laminate surface shall not show a washed-out appearance (characterized by mottled matte and glossy areas or by fibre prominence) nor by blistered or show scaling. Exposed plastic surfaces shall be free of white or colored surface deposits and other contaminants. The etching resist dye shall not penetrate nor stain the base plastic laminate. There shall be no stress cracks at glass weave crossovers. The base laminated plastic shall not soften, split, craze, blister nor delaminate.

6.2 <u>Solder Dip, Etched, Conditioned</u> (Type I Material Only)

6.2.1 Specimen Preparation

Prepare specimen as in paragraph 6.1.1 and condition for 96 hours at 35°C. in an atmosphere of 90% relative humidity.

6.2.2 Test Method

See paragraph 6.1.2

6.2.3 Observation

Examine as in paragraph 6.1.3

6.3 <u>Peel Strength</u>

6.3.1 Specimen Preparation

Prepare specimens of Figure 1 as in paragraph 6.1.1. (Specimen from 6.1.1 may be used)

6.3.2 Test Method and Calculation of Values

The copper foil shall be peeled back approximately 3/4 inch, so that the line of peel is perpendicular to the edge of the specimen. Each specimen shall be clamped or held in a horizontal plane with the peeled copper strip projecting upward for 3/4 inch. The peeled end shall be gripped in a suitable clamp with an attachment to a dial indicator, or tensile testor which has been adjusted to compensate for the weight of the attachment device. The indicator shall be capable of reading in divisions of 0.02 pounds with an accoracy of $\pm$ 5%. The clamp shall cover the full width of the strip and be parallel to the line of peel. The force exerted shall not deviate from the perpendicular by more than 5°. The foil shall be peeled at the rate of 2 inches per minute and the minimum load for at least 1 inch of pull observed and recorded. The load reading shall be converted to pounds per inch or width using the formula:

$$P = \frac{L}{W}$$

Where:

P - Peel Strength in pounds per inch of width.

W - The actual width of the strip at its base; measured with an optical comparator.

L - Load observed, minimum.

A minimum of three (3) strips shall be peel tested on each copper clad side. If the full width of the strip does not peel, the result shall be discarded and a substitute strip selected.

6.4 Peel Strength After Solder Dip

6.4.1 Specimen Preparation

Specimen of 6.1.1 may be used.

6.4.2 Test Method and Calculation of Values

See paragraph 6.3.2

6.5 Insulation Leakage Resistance

The volume resistivity and surface resistance specimens shall be prepared as in Mil-P-13949, except that for surface resistance the pattern of Figure 2 shall be used.

6.5.1 Volume Resistivity

The test shall be performed as in Mil-P-13949.

6.5.2 Surface Resistance

Measurements shall be made as in paragraph 6.5.1, except that the resistance values obtained between terminals 1 and 2, 2 and 3, 3 and 4, and 4 and 5 shall be averaged, and the average shall constitute the value for the specimen.

6.5.3 Conditioning

The tests for insulation leakage resistance shall be performed both at condition A and after 96 hours at 35°C. and 95% R.H.

6.6 Water Absorption

The test method for water absorption and calculation shall be as as specified in Mil-P-13949.

6.7 Dielectric Constant and Dissipation Factor

The test methods and calculations for these properties shall be as specified in Mil-P-13949.

6.8 Flammability

The test method for determining flammability shall be as specified in ASTM D635, except that this method shall be used for all thicknesses.

6.9 Flexural Strength

Flexural strength requirement shall be replaced by the bending against radius as specified in Table III. There should be no evidence of cracking or blistering of base laminate after the test.

TABLE III

Base Material Thickness without copper	Bending Radius
.001" to .008"	3/8"
.009" to .011"	5/8"
.011" to .016"	3/4"

6.10 Solvent and Solution Resistance

6.10.1 Solvent Resistance

The peel strength shall be no less than specified after immersion in each of the following:

a.	Methyl Ethyl Ketone	- 10 minutes at room temp.
b.	Perchlorethylene or Trichlorethylene Vapor	- 2 minutes
c.	Isopropyl Alcohol (99.9% purity)	- 10 minutes at room temp.

6.10.2 Etch Resistance

The specimen of Figure 1 shall be etched in each of the following, and the bond strength shall be no less than is specified in Section 6.3:

a. Chromic Acid Solution consisting of 32 oz./gal. Chromic Acid, 3 oz./gal. Sulfuric Acid, and 2.7 oz./gal. Sodium Sulfate at 130°F. $\pm$ 10°F.

b. Ammonium Persulfate Solution at 130°F.

c. Ferric Chloride, 42° Baume 130°F.

6.10.3 Solvent Absorption

6.10.3.1 Preparation

Specimen size 3 x 3". Etch copper away and dessicate at room temperature for 24 hrs. Weigh individually on an analytical balance (W_1).

6.10.3.2 Test Method

Immerse all specimens in a covered jar containing Trichlorethylene and let stand for 48 hrs. at room temperature. Remove specimens from jar, allow surface solvent to evaporate and weigh specimen (W_2).

6.10.3.3 Calculation

Solvent absorption in calculated as:

$$\frac{100 \ (W_2 - W_1)}{W_1} = \% \text{ gain.}$$

6.11 Weight Loss

6.11.1 Preparation

Specimen size 3 x 3" with copper etched away, and dessicated at room temperature for 24 hrs. Weigh individually on an analytical balance (W_1).

6.11.2 Test Method

Specimens are then placed in an air circulating oven parallel to the air flow and maintained at 163 $\pm$ 3^{o}C. for 2 hours.

Specimens are removed from oven and allowed to cool to room temperature in a desiccator and weighed again (W_2).

6.11.3 Calculation

Weight loss calculated as:

$$\frac{100 \ (W_1 - W_2)}{W_1} = \% \text{ loss.}$$

7.0 QUALITY ASSURANCE PROVISIONS

7.1 Responsibility for Inspection

The supplier shall be responsible for certifying that the material meets the requirements of this specification, and unless otherwise specified shall not be responsible for performing the tests required. Adequate equipment and test facilities shall be maintained in order to perform testing if so required. Equipment shall be of sufficient accuracy and have a frequency of calibration which is to be the satisfaction of the purchaser.

7.2 Acceptance Inspection

7.2.1 Inspection of Product for Delivery

Inspection of product delivered shall consist of groups A and B.

7.2.1.1 Inspection Lot

An inspection lot, shall consist of all the copper clad laminates of the same type designation, produced from the same batches of materials under essentially the same conditions, and offered for inspection at one time.

7.2.1.2 Resubmitted Lots

If an inspection lot is rejected, the supplier may replace it with a new lot, or screen out the defective units, and submit it again for inspection. Resubmitted lots shall be clearly identified as resubmitted lots. Resubmitted lots shall be inspected, using tightened inspection.

7.2.1.3 Group A Inspection

Group A inspection shall consist of the examinations and test specified in Table IV

TABLE IV - GROUP A INSPECTION

Examination	Requirement Paragraph	Method Paragraph	AQL L6 R-2	Specimen Size
Visual and Dimensional	5.1 thru 5.6	- - -	1.0	Full Sheet or Panel
Base Material	5.8 thru 5.12	- - -	1.0	3 x 3
Solder Dip		6.1, 6.2 (Type I only)	1.0	3 x 3
Peel Strength		6.3, 6.4,	1.0	3 x 3 & 3 x 6
Solvent-Solution Resistance		6.10	1.0	3 x 3
Weight Loss		6.11	1.0	3 x 3

7.2.1.4 Sampling Plan

Statistical sampling and inspection shall be in accordance with Standard Mil-Std 105 for ordinary inspection. The acceptable quality levels (AQL) shall be as specified in Table ~~III.~~ IV.

7.2.1.5 Group B Inspection

Group B inspection shall consist of the tests specified in Table V.

TABLE V - GROUP B INSPECTION

Examination	Method Paragraph	AQL	Specimen Size
Volume Resistivity	6.5		Mil-P-13949
Surface Resistance	6.5		2 x 2
Water Absorption	6.6		Mil-P-13949
Dielectric Constant	6.7		Mil-P-13949
Dissipation Factor	6.7		Mil-P-13949
Flammability	6.8		ASTM D635

7.2.1.6 Sampling Plan

Sample Sheets shall be selected from the first lot and thence from each lot of each type designation, in accordance with Table VI. If the number of failures exceeds the acceptance number specified in Table VI, the sample shall be considered to have failed.

TABLE VI - SAMPLING PLAN FOR GROUP B INSPECTION

Total Number of Sheets Produced During Month	Sample Size	Acceptance Number
100 or less	2	0

TABLE VI - SAMPLING PLAN FOR GROUP B INSPECTION (Cont'd)

Total Number of Sheets Produced During Month	Sample Size	Acceptance Number
101 to 1,000 incl.	5	1
1,001 to 10,000 incl.	11	2
10,001 or more	18	3

7.2.1.7 Noncompliance

If a sample fails to pass Group B inspection the supplier shall take corrective action on the process, and on all units of product which can be corrected and which were manufactured under essentially the same conditions, with essentially the same materials, processes, etc., and which are considered subject to the same failure. Acceptance of the produce shall be discontinued until corrective action, acceptable to Photocircuits, has been taken. After the corrective action has been taken, Group A and B inspection shall be repeated on additional sample sheets.

7.3 Qualification Inspection

For purposes of inclusion of a supplier on a qualified products listing, it will be necessary to qualify the specific grade on which approval is desired.

7.3.1 Submission

Qualification of each grade requires the submission of a minimum of two (2) production size sheets.

7.3.2 Testing

For qualification purposes, all tests of Group A and B inspection shall be run on each sheet submitted. Failure of any test shall constitute disqualification and resubmission will be required.

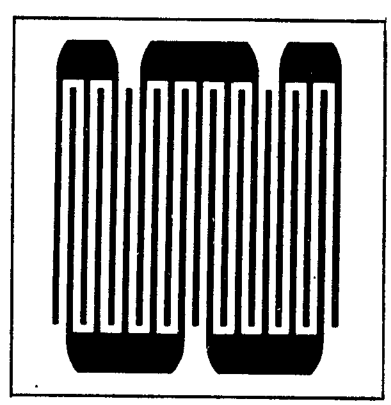
FIGURE 1

Peel Strength
Specimen

Conductor Lines
1/8" Wide on
3" x 3" Specimen

FIGURE 2

Surface Resistance
Specimen



2" x 2" Specimen

8.4 Test Data Sheets

(Results of tests on thin base laminate)

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1466

Manufacturer [redacted]........ Test Begun ......9-10-62................

Grade [redacted].010"x7"x14" 2 oz/2 sides Test Finished ....

Quantity of Shipment ....1.................... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer .SIGNAL..CORP.................

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .....003".......	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0085" Min .0085" Aver .0085"	3	
	Base Laminate Thickness .003"	3	
4.3	Warp and Twist		
	Straight ...Too..Thin......in/in	—	
	Diagonal ...Too..Thin.......in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad .475..°F .....5..Sec	5	
6.2	Solder Dip, Etched 475..°F .....5..Sec	2	
6.3	Solder Dip, Etched C96/35/90 .475.°F .....5..Sec	2	
6.4	Peel Strength, Min 12.00 - 10.60 lbs/in	2	
6.5	Peel Strength, Min 11.20 - 11.20 lbs/in	2	
6.6	Peel Strength, Hot, Min ....lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 .....MΩ"	1	
	Cond C96/35/90 ..144.7 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A ..470 x 10^6 .....MΩ	4	
	Cond C 90/35/90 ..9.0 x 10^5..MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ....004.....%	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ....psi		
	C ....psi		
6.11	Cond E/150 L ....psi		
	C ....psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ....lb/in		

Retest: Para. ....

Solvent Absorption 8.00 %
Weight Loss 0.494 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number ..sample..... and ☐ conforms ☐ Does not conform.

.... Quality Control

Emanuel Gabate .... Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1467

Manufacturer [redacted] .... Test Begun 9-10-62

Grade [redacted] .008"x 7"x 14" 2 oz/2 sides Test Finished ....

Quantity of Shipment 1 .... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .003"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .009" Min .009" Aver .009"	3	
	Base Laminate Thickness .004"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad 475 °F 5 Sec	5	
6.2	Solder Dip, Etched 475 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 475 °F 5 Sec	2	
6.4	Peel Strength, Min 12.00 - 11.60 lbs/in	2	
6.5	Peel Strength, Min 9.20 - 9.20 lbs/in	2	
6.6	Peel Strength, Hot, Min .... lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 MΩ"	1	
	Cond C96/35/90 720.0 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A 720.0 x 10^6 MΩ	4	
	Cond C 90/35/90 6.0 x 10^6 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .006 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L .... psi		
	C .... psi		
6.11	Cond E/150 L .... psi		
	C .... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance .... lb/in		

Retest: Para. ....

Solvent Absorption 17.69 %
Weight Loss 0.537 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample ..... and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Cabato (signature)
Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1468

Manufacturer [redacted] .... Test Begun .... 9-10-62 ....

Grade [redacted] .008" x 7" x 14" .. 1oz/2 sides Test Finished ....

Quantity of Shipment .... 1 .... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer ... SIGNAL CORP. ....

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. ...... .0018"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0075" Min .0075" Aver .0075"	3	
	Base Laminate Thickness .005"	3	
4.3	Warp and Twist		
	Straight ..... Too Thin ...... in/in	—	
	Diagonal .... Too Thin ...... in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad .. 475 .°F ..... 5 .Sec	5	
6.2	Solder Dip, Etched .. 475 .°F ..... 5 .Sec	2	
6.3	Solder Dip, Etched C96/35/90 .. 475 .°F ..... 5 .Sec	2	
6.4	Peel Strength, Min 7.60 - 7.60 .lbs/in	2	
6.5	Peel Strength, Min 7.60 - 7.20 .lbs/in	2	
6.6	Peel Strength, Hot, Min .... lbs/in		
6.7.1	Volume Resistivity		
	Cond A . 720.0 x 10⁶ ..... MΩ[illegible]"	1	
	Cond C96/35/90 172.4 x 10⁶ .MΩ[illegible]"	1	
6.7.2	Surface Resistance		
	Cond A .. 720.0 x 10⁶ ..... MΩ	4	
	Cond C 90/35/90 2.7 x 10⁶ .MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .... .006 ..... %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L .... psi		
	C .... psi		
6.11	Cond E/150 L .... psi		
	C .... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance .... lb/in		

Retest: Para. ....

Solvent Absorption 12.32%

Weight Loss 0.45%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number ... Sample ... and ☐ conforms ☐ Does not conform.

.... Emanuel Abate ......

Quality Control Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1469

Manufacturer [redacted] .... Test Begun .... 9-10-62 ....

Grade [redacted] .005"x7"x14" 2oz/2 sides Test Finished ....

Quantity of Shipment ....1.... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer ..SIGNAL..CORP.......

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .....0032".....	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .012" Min .012" Aver .012"	3	
	Base Laminate Thickness .007"	3	
4.3	Warp and Twist		
	Straight ...Too..Thin......in/in	—	
	Diagonal ..Too..Thin......in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad .475..°F ....5..Sec	5	
6.2	Solder Dip, Etched .475..°F ....5..Sec	2	
6.3	Solder Dip, Etched C96/35/90 .475..°F ....5..Sec	2	
6.4	Peel Strength, Min 14.00-14.00 lbs/in	2	
6.5	Peel Strength, Min .14.00-13.60 lbs/in	2	
6.6	Peel Strength, Hot, Min ....lbs/in		
6.7.1	Volume Resistivity		
	Cond A ..7.20..x..10⁶...MΩ"	1	
	Cond C96/35/90 .51.35x10⁶ MΩ"	1	
6.7.2	Surface Resistance		
	Cond A ...4.0.x.10⁶........MΩ	4	
	Cond C 90/35/90 ..6.5.x.10⁵..MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ....015......%	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ....psi		
	C ....psi		
6.11	Cond E/150 L ....psi		
	C ....psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ....lb/in		

Retest: Para. ....

Solvent Absorption 3.12 %

Weight Loss 0.964 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number .Sample..... and ☐ conforms ☐ Does not conform.

.... Quality Control

Emanuel [signature] Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1470

Manufacturer [redacted] Test Begun 9-10-62

Grade [redacted] .001" x 8" x 20" 2 oz/2 sides Test Finished

Quantity of Shipment 1 ☐ Sheets ☒ Panels Other

Sampling Plan Used ☒ Mil-105A Other Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .0032"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .007" Min .007" Aver .007"	3	
	Base Laminate Thickness .0015"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad 475 °F 5 Sec	5	
6.2	Solder Dip, Etched 475 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90		
	475 °F 5 Sec	2	
6.4	Peel Strength, Min 10.80-10.40 lbs/in	2	
6.5	Peel Strength, Min 10.80-10.70 lbs/in	2	
6.6	Peel Strength, Hot, Min lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10⁶ MΩ cm	1	
	Cond C96/35/90 13.178 x 10⁶ MΩ cm	1	
6.7.2	Surface Resistance		
	Cond A 45 x 10⁶ MΩ	4	
	Cond C 90/35/90 3.6 x 10⁴ MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .009 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L psi		
	C psi		
6.11	Cond E/150 L psi		
	C psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance lb/in		

Retest: Para.

Solvent Absorption 15.10 %

Weight Loss 0.419 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number sample .... and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Abate
Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1471

Manufacturer [redacted] ..... Test Begun ...... 9-10-62 ....

Grade [redacted] ...003" x 8" x 20" .. 2oz/2 sides Test Finished ....

Quantity of Shipment .... 1 .... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer .. SIGNAL ... CORP ....

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Con-forms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. ...... .003"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .008" Min .008" Aver .008"	3	
	Base Laminate Thickness .0025"	3	
4.3	Warp and Twist		
	Straight .... Too ... Thin ...... in/in	—	
	Diagonal ... Too ... Thin ...... in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad .. 475 .°F .... 5 .. Sec	5	
6.2	Solder Dip, Etched .. 475 .. °F .... 5 .. Sec	2	
6.3	Solder Dip, Etched C96/35/90		
	475 .. °F ... 5 .. Sec	2	
6.4	Peel Strength, Min 14.00 - 14.00 lbs/in	2	
6.5	Peel Strength, Min .11.20 - 10.80 lbs/in	2	
6.6	Peel Strength, Hot, Min .... lbs/in		
6.7.1	Volume Resistivity		
	Cond A .. 720.0 x 10⁶ ... MΩ"	1	
	Cond C96/35/90 153.75 x 10⁶ MΩ"	1	
6.7.2	Surface Resistance		
	Cond A ... 3.4 .. x 10⁶ ...... MΩ	4	
	Cond C 90/35/90 .. .55 x 10⁶ . MΩ	4	

	TEST RESULTS	Con-forms	Does not Conf.
6.8	Water Absorption .... .005 ...... %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L .... psi		
	C .... psi		
6.11	Cond E/150 L .... psi		
	C .... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance .... lb/in		

Retest: Para. ....

Solvent Absorption 9.57 %

Weight Loss 0.205%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number .. Sample .... and ☐ conforms ☐ Does not conform.

.... Erasmo Abato ....

Quality Control Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1472

Manufacturer [redacted] Test Begun 9-10-62

Grade [redacted] .003" x 8" x 20" 2 oz/2 sides Test Finished

Quantity of Shipment 1 ☐ Sheets ☒ Panels Other

Sampling Plan Used ☒ Mil-105A Other Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .003"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .009" Min .009" Aver .009"	3	
	Base Laminate Thickness .0045"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad 475 °F 5 Sec	5	
6.2	Solder Dip, Etched 475 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 475 °F 5 Sec	2	
6.4	Peel Strength, Min 10.00 - 10.00 lbs/in	2	
6.5	Peel Strength, Min 10.00 - 9.30 lbs/in	2	
6.6	Peel Strength, Hot, Min ... lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 MΩ"	1	
	Cond C96/35/90 52.07 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A .83 x 10^6 MΩ	4	
	Cond C 90/35/90 0.5 x 10^6 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .014 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ... psi		
	C ... psi		
6.11	Cond E/150 L ... psi		
	C ... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ... lb/in		

Retest: Para.

Solvent Absorption 15.85 %
Weight Loss 0.469 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Abate
Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1473

Manufacturer [redacted]
Test Begun 9-10-62

Grade [redacted] .008" x 8" x 20" 1 oz/2 sides
Test Finished

Quantity of Shipment 1
☐ Sheets ☒ Panels Other

Sampling Plan Used ☒ Mil-105A Other
Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .0017"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .010" Min .010" Aver .010"	3	
	Base Laminate Thickness .007"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E (G) F P	3	
6.1	Solder Dip, Clad 475 °F 5 Sec	5	
6.2	Solder Dip, Etched 475 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 475 °F 5 Sec	2	
6.4	Peel Strength, Min 8.00 - 8.00 lbs/in	2	
6.5	Peel Strength, Min 8.00 - 8.00 lbs/in	2	
6.6	Peel Strength, Hot, Min lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 MΩ"	1	
	Cond C96/35/90 1.46-1.25 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A 2.50 x 10^6 MΩ	4	
	Cond C 90/35/90 55 x 10^5 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .006 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L psi		
	C psi		
6.11	Cond E/150 L psi		
	C psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance lb/in		

Retest: Para. .... Para.

Solvent Absorption 9.36%
Weight Loss 0.376%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel [signature]
Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1497

Manufacturer [redacted] .... Test Begun .... 9-19-62 ....

Grade [redacted] .012"x8"x8" 2oz/2 sides Test Finished ....

Quantity of Shipment .... 2 .... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer .. SIGNAL CORP. ....

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .... .0028"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .014" Min .014" Aver .014"	3	
	Base Laminate Thickness .009"	3	
4.3	Warp and Twist		
	Straight .... Too Thin .... in/in	—	
	Diagonal .... Too Thin .... in/in	—	
4.4	Machinability E G F P (G circled)	6	
6.1	Solder Dip, Clad 475 °F .... 5 Sec	5	
6.2	Solder Dip, Etched 475 °F .... 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 .475 °F .... 5 Sec	2	
6.4	Peel Strength, Min .8.00 - 7.20 lbs/in	2	
6.5	Peel Strength, Min .8.40 - 8.00 lbs/in	2	
6.6	Peel Strength, Hot, Min .... lbs/in		
6.7.1	Volume Resistivity		
	Cond A ... 720.0 x 10^6 ... MΩ"	1	
	Cond C96/35/90 .262.5 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A . 720.0 x 10^6 ...... MΩ	4	
	Cond C 90/35/90 .4.5 x 10^6 .MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .... .005 .... %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L .... psi		
	C .... psi		
6.11	Cond E/150 L .... psi		
	C .... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance .... lb/in		

Retest: Para. ....

Solvent Absorption 5.30 %

Weight Loss 0.419%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number .sample..... and ☐ conforms ☐ Does not conform.

.... Emanuel Albats ....

Quality Control Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1498

Manufacturer [redacted] Test Begun ....

Grade [redacted] .005" x 5½" x 11" 2 oz / 2 sides Test Finished ....

Quantity of Shipment 1 .... ☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .003"	6	
4.1.2	Base Laminate Appearance		2
4.2	Overall Thickness		
	Max .011" Min .011" Aver .011"	3	
	Base Laminate Thickness .0055"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P (G circled)	6	
6.1	Solder Dip, Clad 475 °F 5 Sec		5
6.2	Solder Dip, Etched 475 °F 5 Sec		1
6.3	Solder Dip, Etched C96/35/90 475 °F 5 Sec		1
6.4	Peel Strength, Min 11.80 - 10.40 lbs/in	2	
6.5	Peel Strength, Min ....lbs/in		
6.6	Peel Strength, Hot, Min ....lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 MΩ [redacted]"	1	
	Cond C96/35/90 466.8 x 10^6 MΩ [redacted]"	1	
6.7.2	Surface Resistance		
	Cond A 720.0 x 10^6 MΩ	4	
	Cond C 90/35/90 3.5 x 10^6 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .008 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ....psi		
	C ....psi		
6.11	Cond E/150 L ....psi		
	C ....psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ....lb/in		

Retest: Para. ....

Solvent Absorption 0.89 %

COMMENTS: Copper Clad mylar

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample .... and ☐ conforms ☐ Does not conform.

.... Quality Control

Emanuel [signature] Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1499

Manufacturer [redacted] Test Begun 9-19-62

Grade [redacted] .005" x 5½" x 11" 1oz/2 sides Test Finished

Quantity of Shipment 1 ☐ Sheets ☒ Panels Other

Sampling Plan Used ☒ Mil-105A Other Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .0015"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0045" Min .0045" Aver .0045"	3	
	Base Laminate Thickness .0018"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P (G circled)	3	
6.1	Solder Dip, Clad 475 °F 5 Sec	5	
6.2	Solder Dip, Etched 475 °F 5 Sec	1	
6.3	Solder Dip, Etched C96/35/90 475 °F 5 Sec	1	
6.4	Peel Strength, Min 6.80 lbs/in	1	
6.5	Peel Strength, Min 6.80 lbs/in	1	
6.6	Peel Strength, Hot, Min lbs/in		
6.7.1	Volume Resistivity		
	Cond A >20.0 x 10^6 MΩ-in"	1	
	Cond C96/35/90 >8.10.0 x 10^6 MΩ-in"	1	
6.7.2	Surface Resistance		
	Cond A >35.0 x 10^6 MΩ	4	
	Cond C 90/35/90 1.0 x 10^6 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .005 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L psi		
	C psi		
6.11	Cond E/150 L psi		
	C psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance lb/in		

Retest: Para.

Solvent Absorption 7.66 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample .... and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Webster
Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1500

Manufacturer [redacted] .... Test Begun .... 9-19-62 ....

Grade [redacted] .008" x 6" x 12" .602/

Test Finished ....

Quantity of Shipment ....1....................

☐ Sheets ☒ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other ....

Customer ..SIGNAL..CORP........

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. ......0014"...	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0072" Min .0074" Aver .0075"	5	
	Base Laminate Thickness .0062"	3	
4.3	Warp and Twist		
	Straight ...Too..Thin.......in/in	—	
	Diagonal ...Too...Thin.....in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad .412...°F 5.Sec	5	
6.2	Solder Dip, Etched .412..°F 5.Sec	1	
6.3	Solder Dip, Etched C96/35/90		
	..472.°F ...5...Sec	1	
6.4	Peel Strength, Min .14.00........lbs/in	1	
6.5	Peel Strength, Min ..14.80......lbs/in	1	
6.6	Peel Strength, Hot, Min ....lbs/in		
6.7.1	Volume Resistivity		
	Cond A ...>20.0 x 10^6..MΩCm	1	
	Cond C96/35/90 ..>[illegible] x 10^6 MΩCm	1	
6.7.2	Surface Resistance		
	Cond A .>20.0 x 10^6......MΩ	4	
	Cond C 90/35/90 ..5.0 x 10^5.MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ....016.....%	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ....psi		
	C ....psi		
6.11	Cond E/150 L ....psi		
	C ....psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ....lb/in		

Retest: Para. ....

Solvent Obsorption 7.86 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number ..Sample..... and ☐ conforms ☐ Does not conform.

.... Quality Control

Emanuel Albate .... Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1526

Manufacturer [redacted] .... Test Begun .... 10-4-62 ....

Grade [redacted] .004" x 18" x 36" 2 oz/2 sides Test Finished ....

Quantity of Shipment ..... 1 .... ☒ Sheets ☐ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer .. SIGNAL CORP. ....

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .... .003"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .009" Min .009" Aver .009"	3	
	Base Laminate Thickness .0045"	3	
4.3	Warp and Twist		
	Straight .... Too Thin ...... in/in	—	
	Diagonal ... Too Thin ...... in/in	—	
4.4	Machinability E (G) F P	3	
6.1	Solder Dip, Clad 415 °F ..... 5 Sec	5	
6.2	Solder Dip, Etched 415 °F ..... 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90		
	415 °F ..... 5 Sec	2	
6.4	Peel Strength, Min 14.00 - 13.80 lbs/in	2	
6.5	Peel Strength, Min 11.20 - 10.88 lbs/in	2	
6.6	Peel Strength, Hot, Min .... lbs/in		
6.7.1	Volume Resistivity		
	Cond A .. 720.0 x 10⁶ .... MΩ"	1	
	Cond C96/35/90 .24.375 x 10⁶ MΩ"	1	
6.7.2	Surface Resistance		
	Cond A ... 720.0 x 10⁶ .... MΩ	4	
	Cond C 90/35/90 . 5.0 x 10⁵ .. MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ...... .50 .... %		
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L .... psi		
	C .... psi		
6.11	Cond E/150 L .... psi		
	C .... psi		
6.12	Flammability		
6.13.1	Solvent Resistance 12.00	2	
6.13.2	Etch Resistance .... 15.26 ..	1	
6.13.3	Cyanide Resistance .... lb/in		

Retest: Para. ....

Solvent Absorption 18.84%

Weight Loss 0.465%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number .. sample .... and ☐ conforms ☐ Does not conform.

.... Emanuel Labate ....

Quality Control   Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1527

Manufacturer [redacted] .... Test Begun ....10-4-62..................

Grade [redacted] .008" x 18" x 36" . 2 oz/2 sides. Test Finished ....

Quantity of Shipment ....1........................ ☒ Sheets ☐ Panels Other ....

Sampling Plan Used ☒ Mil-105A Other .... Customer ..SIGNAL...CORP.................

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. ....003"......	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0135" Min .0135" Aver .0135"	3	
	Base Laminate Thickness .0085"	3	
4.3	Warp and Twist		
	Straight ...Too..Thin.......in/in	—	
	Diagonal ..Too..Thin.......in/in	—	
4.4	Machinability E (G) F P	6	
6.1	Solder Dip, Clad .500..°F ....5..Sec	5	
6.2	Solder Dip, Etched .500..°F ....5..Sec	2	
6.3	Solder Dip, Etched C96/35/90 .500..°F 5.Sec	2	
6.4	Peel Strength, Min 14.60 - 13.60 lbs/in	2	
6.5	Peel Strength, Min 12.82 - 12.80 lbs/in	2	
6.6	Peel Strength, Hot, Min ....lbs/in		
6.7.1	Volume Resistivity		
	Cond A ..720.0 x 10^6....MΩcm	1	
	Cond C96/35/90 .15.54 x 10^6 MΩcm	1	
6.7.2	Surface Resistance		
	Cond A ..720.0 x 10^6......MΩ	4	
	Cond C 90/35/90 2.75 x 10^5..MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ....40.....%		
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L ....psi		
	C ....psi		
6.11	Cond E/150 L ....psi		
	C ....psi		
6.12	Flammability		
6.13.1	Solvent Resistance 10.40 / 11.52	2 / 1	
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance ....lb/in		

Retest: Para. ....

Solvent Absorption 6.75 %
Weight Loss 0.215 %

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number ...Sample... and ☐ conforms ☐ Does not conform.

.... Emanuel Alberto ......

Quality Control Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1528

Manufacturer [redacted] Test Begun 10-4-62

Grade [redacted] .012" x 18" x 36" 2 oz/2 sides Test Finished

Quantity of Shipment 1 ☒ Sheets ☐ Panels Other

Sampling Plan Used ☒ Mil-105A Other Customer SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .003"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0165" Min .0165" Aver .0165"	3	
	Base Laminate Thickness .0115"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P	6	
6.1	Solder Dip, Clad 500 °F 5 Sec	5	
6.2	Solder Dip, Etched 500 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 500 °F 5 Sec		2
6.4	Peel Strength, Min 12.80-12.40 lbs/in	2	
6.5	Peel Strength, Min 12.60-12.80 lbs/in	2	
6.6	Peel Strength, Hot, Min lbs/in		
6.7.1	Volume Resistivity		
	Cond A 720.0 x 10^6 MΩ[redacted]"	1	
	Cond C96/35/90 59.09 x 10^6 MΩ[redacted]"	1	
6.7.2	Surface Resistance		
	Cond A 720.0 x 10^6 MΩ	4	
	Cond C 90/35/90 7.5 x 10^5 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .29 %	2	
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L psi		
	C psi		
6.11	Cond E/150 L psi		
	C psi		
6.12	Flammability		
6.13.1	Solvent Resistance 11.20	2	
6.13.2	Etch Resistance 12.80	/	
6.13.3	Cyanide Resistance lb/in		
	Retest: Para.		
	Solvent Absorption 6.34%		
	Weight Loss 0.40%		

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Abate

Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1559

Manufacturer [redacted] ... Test Begun ... 10-19-62 ...

Grade [redacted] .016" ±.003" x 36" x 48" 2 oz./2 sides Test Finished ...

Quantity of Shipment ... 1 ... ☒ Sheets ☐ Panels Other ...

Sampling Plan Used ☒ Mil-105A Other ... Customer SAMPLE - SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance ...	2	
	Thickness—Aver. ... .0032" ...	6	
4.1.2	Base Laminate Appearance ...	2	
4.2	Overall Thickness		
	Max .0165" Min .0165" Aver .0165"	3	
	Base Laminate Thickness .011"	3"	
4.3	Warp and Twist		
	Straight ... Too Thin ... in/in	—	
	Diagonal ... Too Thin ... in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad 500 °F ... 5 Sec	5	
6.2	Solder Dip, Etched 500 °F ... 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90		
	500 °F ... 5 Sec	2	
6.4	Peel Strength, Min 10.00 - 10.00 lbs/in	2	
6.5	Peel Strength, Min 10.80 - 10.80 lbs/in	2	
6.6	Peel Strength, Hot, Min ... lbs/in		
6.7.1	Volume Resistivity		
	Cond A ... 720.0 x 10^6 ... MΩ[redacted]"	1	
	Cond C96/35/90 373.0 x 10^6 MΩ[redacted]"	1	
6.7.2	Surface Resistance		
	Cond A ... 720.0 x 10^6 ... MΩ	4	
	Cond C 90/35/90 ... 8.0 x 10^6 ... MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption ... .58 %		
6.9	Dielectric Constant ...		
6.9	Dissipation Factor ...		
6.10	Flexural Strength		
	Cond A L ... psi		
	C ... psi		
6.11	Cond E/150 L ... psi		
	C ... psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance ...		
6.13.3	Cyanide Resistance ... lb/in		

Retest: Para. ...

Solvent Absorption 0.39%

Weight Loss 0.313%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ..., and P. O. Number ... Sample ... and ☐ conforms ☐ Does not conform.

Quality Control ...

Emanuel Schutz

Test Technician

PHOTOCIRCUITS CORPORATION
MATERIAL CONFORMANCE REPORT

№ 1560

Manufacturer [redacted] Test Begun 10-19-62

Grade [redacted] .008" x 37" x 42" 2oz/2 sides Test Finished

Quantity of Shipment 1 ☒ Sheets ☐ Panels Other

Sampling Plan Used ☒ Mil-105A Other Customer SAMPLE - SIGNAL CORP.

All results shall conform to #500 Purchasing and Engineering Specification. Numerical listing refers to respective paragraphs of #500 Specification.

	TEST RESULTS	Conforms	Does not Conf.
4.1.1	Copper Foil—Appearance	2	
	Thickness—Aver. .0028"	6	
4.1.2	Base Laminate Appearance	2	
4.2	Overall Thickness		
	Max .0125" Min .0125" Aver .0125"	3	
	Base Laminate Thickness .007"	3	
4.3	Warp and Twist		
	Straight Too Thin in/in	—	
	Diagonal Too Thin in/in	—	
4.4	Machinability E G F P	3	
6.1	Solder Dip, Clad 500 °F 5 Sec	5	
6.2	Solder Dip, Etched 500 °F 5 Sec	2	
6.3	Solder Dip, Etched C96/35/90 500 °F 5 Sec		2
6.4	Peel Strength, Min 9.60 - 9.80 lbs/in	2	
6.5	Peel Strength, Min 9.60 - 9.60 lbs/in	2	
6.6	Peel Strength, Hot, Min lbs/in		
6.7.1	Volume Resistivity		
	Cond A >20.0 x 10^6 MΩ"	1	
	Cond C96/35/90 50.4 x 10^6 MΩ"	1	
6.7.2	Surface Resistance		
	Cond A >20.0 x 10^6 MΩ	4	
	Cond C 90/35/90 3.5 x 10^6 MΩ	4	

	TEST RESULTS	Conforms	Does not Conf.
6.8	Water Absorption .42 %		
6.9	Dielectric Constant		
6.9	Dissipation Factor		
6.10	Flexural Strength		
	Cond A L psi		
	C psi		
6.11	Cond E/150 L psi		
	C psi		
6.12	Flammability		
6.13.1	Solvent Resistance		
6.13.2	Etch Resistance		
6.13.3	Cyanide Resistance lb/in		

Retest: Para.

Solvent Absorption 9.83%

Weight Loss 0.353%

COMMENTS:

The preceding tests have been performed in accordance with specification 500 and customer spec ...., and P. O. Number Sample and ☐ conforms ☐ Does not conform.

Quality Control

Emanuel Abate
Test Technician

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